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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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CONTENTS

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JOURNAL
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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 July, 1946 No. 1

REPORT OF THE SUBCOMMITTEE ON 16-MM FILM SPLICES*

Introduction.—A splice is a little thing; and being little, it has been given but little attention. If we are to take heed of the advice of our Scotch friends, we must remember that "many a mickle makes a muckle—" and pay more attention to our splices.

Before World War II, little was published upon the subject of 16-mm splices. They were discussed in the Standards Committee of our Society, but the subject matter was then, as now, considered rather dull and of interest to only a very small group that was faced with splicing problems and was forced through circumstances to do something about them. But the volume of 16 mm has grown from a mere trickle of release prints to an imposing volume of some 400 million linear feet more or less, manufactured in the last year. This volume is now too large to be ignored; the problem of splicing 16 mm is now going to affect too many people with many diverse interests.

Definition.—What is a splice, and how does a splice come into being? John Andreas, that patient man who spent most of his odd moments during 2 years compiling a "Glossary of Terms Dealing with the Motion Picture Art"[1] defined a splice as "Any type of cement or mechanical fastening by which two separate lengths of film are united end-to-end so as to function as a single piece of film when passing through a camera, film processing machine, or projector." The Glossary of Technical Terms[2] did not define a splice but did define splicing as "Joining the ends of film by cementing." Although Subcommittee *C* of Z52, the War Committee on Photography and Cinematography of the American Standards Association did not write a definition of a splice for the War Standard "Nomenclature for Motion Picture Film Used in Studios and Processing Labora-

*Presented May 10, 1946, at the Technical Conference in New York.

tories" (Z52.14-1944), it did spend some time preparing a new standard for 16-Mm Sound Splices, Z52.20. But that is getting ahead of the story.

Splices in Release Prints.—We must remember that splices have a number of functions; one of the most talked about is that of repairing a torn film. If a film becomes torn in use, it is either worn out, or it has been subjected to carelessness in handling or run on a poor machine. Despite the proverbially poor operating condition of 16-mm machines, film damage seems surprisingly low for the amount of film projected if one judges by the insurance rates in force in most circulating film libraries. Possibly repair can be considered one of the lesser functions of a splice. Repair splices are customarily made by the film user; less frequently by a circulating library.

A new print—one just out of the laboratory—starts its life with a minimum of 2 splices—one that attaches the head leader to the print and the other that attaches the tail leader to the print. Most prints have at least one more splice per 400-ft roll; this one additional splice was permitted in American War Standard Z52.3. There was much discussion about this extra splice. Those in favor of it felt that film life was not seriously reduced thereby and that the life disadvantage was more than offset, as the "short ends" accumulated in printing would be better utilized. (Short ends accumulate when the film to be printed is an odd length, not a multiple of 400 ft, the unit length for film supplied as raw stock.) By the way, it is well to remember at this point that most 16-mm films used during the war by the Services were *not* run to the wear-out point.

A new print obtained from a laboratory today may contain more than the number of splices just mentioned; poor grade prints are likely to have many more. It should be noted that an unspliced print will normally show an appreciably longer life than a spliced print particularly on machines with sharp bends in the film path. An unspliced print will avoid that distressing phenomenon known as the splice jump which occurs when a splice passes through the projector movement. For practical purposes, a print may be considered optional with respect to splices when sufficient film is provided on the head end and on the tail end of the picture proper to permit replacement of the leaders some 5 or 6 times—and when the print has *no* splices within the picture proper.

All through this discussion of splices in release prints, we have assumed that the picture proper will appear as a positive; negative-

type images are not customarily used in release prints and for the purpose of this discussion, will be considered unusual.

Splices in the Original.—Let us pass over for the time being what happens in the laboratory and consider the original film in relation to splices. For the purposes of this paper, we need not consider 35-mm film. Customarily, a 35-mm splice is made in the negative and is of such width that no portion of it appears within the 16-mm projector aperture when a reduction print is projected. We cannot discuss 8-mm splices at this point as the 8-mm situation will be reviewed after the 16-mm solutions are under way. In considering 16-mm original material, it is well to consider what original

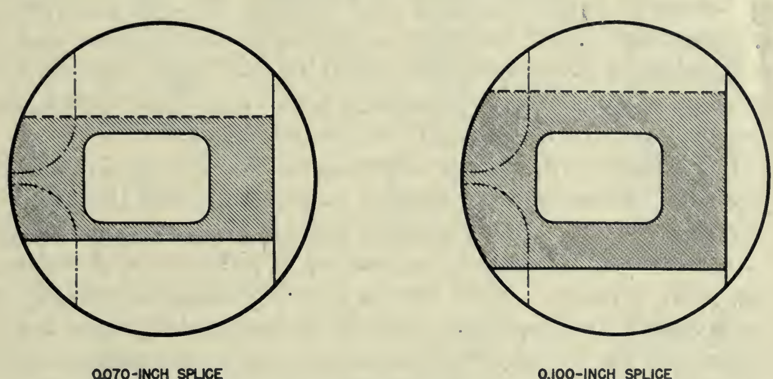


FIG. 1. Relative 16-mm splice encroachments on picture area.

picture material may be and what 16-mm original sound material may be.

Although 35-mm picture originals almost invariably are negatives, 16-mm picture originals are almost invariably reversals or direct positives. Good examples are Kodachrome, Ansco Color, and black-and-white reversal original. It is only in special cases that negative is used as original material.

If we examine a splice made with any present-day commercial splicing machine we invariably find that the splice encroaches upon the picture image appearing in the projector aperture. Fig. 1 shows the amount of encroachment involved with splices of 2 different widths, namely, 0.070 in. and 0.100 in. Our 16-mm splice *does* encroach with *either* dimension—quite a different situation from that encountered with 35 mm. Needless to say, the diagonal splice is located diagonally across the spliced frame in the picture.

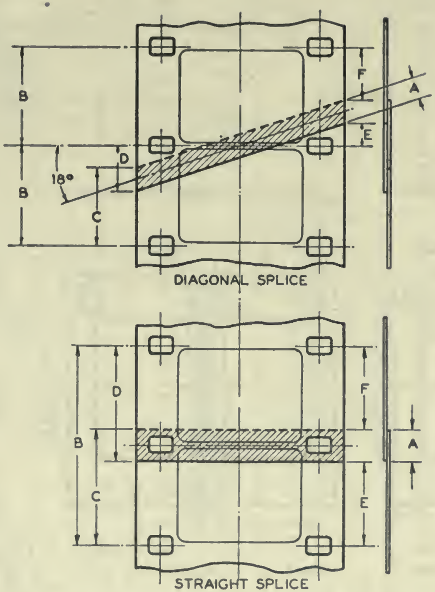
Even if we are extremely careful in making splices, either splice appearing in the original will appear in every release print made because of the encroachment. As present-day 16-mm subjects of commercial origin may have as many as 150 splices in a single 400-ft roll (and it is not unusual to find 80 as a typical average), the importance of making every splice a good unobtrusive one can hardly be overemphasized. Fortunately, splices made in original reversal and in color reversal show up much less objectionably than like splices made in original negative material. If 0.070-in. straight splices are neatly and cleanly made, they will be almost invisible in the release print particularly if the edges of the splice are carefully painted out or "blooped" in the assembled original film. (Blooping may be the incorrect term as we refer here to treatment of the picture and not of the sound.) Needless to say, the 0.100-in. straight splice and the 0.070-in. diagonal are not capable of a neat and workmanlike result when compared with the 0.070-in. straight splice.

The situation with regard to splicing the sound original is different from that of the picture original. In the past, most 16-mm sound originals were recorded as nonpush-pull negatives. We may expect a very material increase in the number of direct sound positives in the years to come. Most 16-mm sound originals fortunately are *not* recorded simultaneously with the taking of the picture but are scored *afterward* (with off-stage voice) in accordance with the timing established by means of a "shot list" (cue sheet) made from the picture.[3] With a competent staff and with suitable recording facilities, there is little reason for more than 2 or 3 splices. One of these is used to attach the head leader to the original and another to attach the tail leader to the original. If more than these 2 splices are required, a sound bloop will be needed for each additional splice.

There is no point in discussing the splicing of the sound original further; your Subcommittee needs data on practices both present and contemplated about sound splicing in 16 mm, and also 16-mm sound blooping. It seems difficult to consider the two separately if we are to be logical about our work.

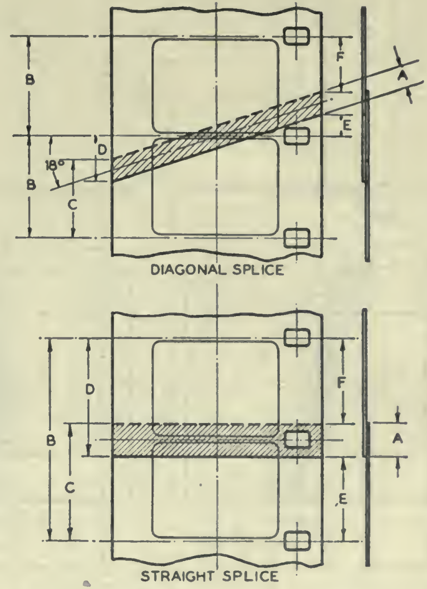
For the present we may say that it is customary in most cases to use the same kind of splice for original sound as for original picture. The procedure, however, must be recognized as an arbitrary one since the diagonal splice has certain advantages in splicing sound film.

Splices Made at Other Stages Intermediate Between the Original



	Diagonal Mm	Diagonal In. Equiv.	Straight Mm	Straight In. Equiv.
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

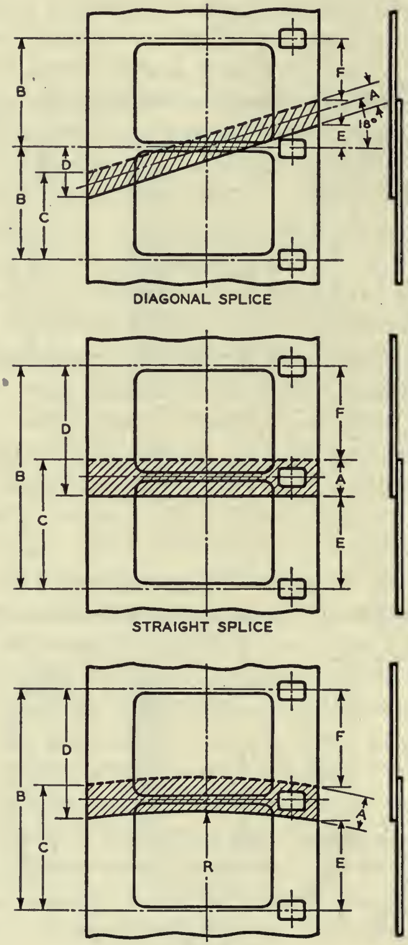
A



	Diagonal Mm	Diagonal In. Equiv.	Straight Mm	Straight In. Equiv.
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

B

FIG. 2. *A*—Dimensions and dimensioning practice used in Z22.24-1941; *B*—Used in Z22.25-1941.



	Diagonal		Straight		Curved	
	Mm	*In. Equiv.*	*Mm*	*In. Equiv.*	*Mm*	*In. Equiv.*
A (MAX)	1.78	0.070	1.78	0.070	1.78	0.070
B	7.62	0.300	15.24	0.600	15.24	0.600
C (MAX)	5.97	0.235	8.51	0.335	8.51	0.335
D (MAX)	3.53	0.139	8.51	0.335	8.51	0.335
E (MIN)	1.65	0.065	6.74	0.265	6.73	0.265
F (MIN)	4.09	0.161	6.74	0.265	6.73	0.265
R					105.0	4.125

FIG. 3. Dimensions and dimensioning practice used in Z52.20-1944.

and the Release Print.—It must be recognized that splices are made on intermediate films used in the laboratory and in editing. For the moment, we shall not discuss such splices as their specialized natures usually dictate how they are made. Your committee will appreciate receiving data on the splices used for this purpose and the reasons governing their choice.

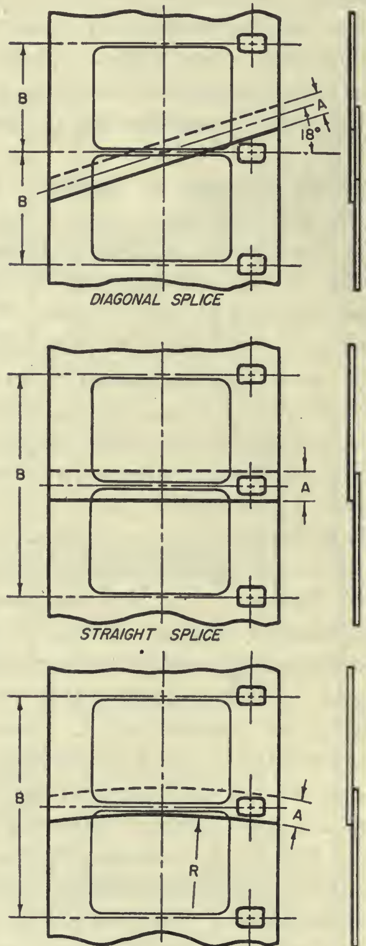
The Standardization History of Splices.—Having mentioned briefly where splices are used, let us now examine what has been done in considering the standardization of splices.

Before World War II, two standards were approved through the ASA; one for silent film Z22.24-1941 "16-Mm Film Splices—Negative and Positive" and one for sound film, Z22.25-1941 similarly titled. Both are shown in Fig. 2. In both cases the standard width for a diagonal splice was 0.070 in. and the standard width for straight splices was 0.100 in. regardless of whether the film is silent or sound, or whether the film is negative or positive, and regardless of whether the film is an original, a release print, or any other intermediate film.

When Z52 studied the splice question, the American War Standard Z52.20-1944 "Positive and Negative Splices for Processed 16-Mm Sound Motion Picture Film" was approved and issued. Dimensions and dimensioning practice used are shown in Fig. 3. The width called for in the straight splice was reduced to a *maximum* of 0.070 in. in all cases. Please note that this width had previously been specified *only* for the diagonal splice. Please note further that a new type of splice appeared in the Z52 standard—the curved splice.

As War Standards are not valid beyond the end of the war, the ASA Sectional Committee on Motion Pictures Z22 required a review of the existing War Standards. During the war, conflict between the older Z22.25 and the newer Z52.20 was automatically reconciled in favor of the War Standard. With the end of the war, the subject was called for review to determine what would be desirable as a regular American Standard. Thus the subject was referred by Committee Z22 back to the SMPE. The Standards Committee of the SMPE set up the present Subcommittee. To get the earliest action possible, the Subcommittee was authorized to study and recommend 16-mm splices; the purpose was to resolve the conflict between the Z22.25 and the Z52.20 Standards.

The present Subcommittee was appointed with the author as Chairman and film manufacturers, splicer manufacturers, and splicer users represented. The first meeting was held January 23, 1946,



	Diagonal		Straight		Curved	
	In.	*Mm*	*In.*	*Mm*	*In.*	*Mm*
A (MAX)	0.070	1.78	0.070	1.78	0.070	1.78
B	0.300	7.62	0.600	15.24	0.600	15.24
R					4.125	104.78

Note 1. Dimension *A* is maximum and a narrower width splice of adequate strength is desirable.
Note 2. The diagonal splice is symmetrical about the center of the included frameline.
Note 3. The straight splice is symmetrical about the included perforation.
Note 4. The curved splice is symmetrical about the included perforation.
Note 5. The center of radius *R* is on the film centerline.

FIG. 4. Dimensions and dimensioning practice for 16-mm sound splices as proposed for a one-year trial.

The minutes of that meeting showed rather clearly that the splice problem is in need of considerable study. The views of many of those present showed points of common thought but a number of unsolved problems were uncovered. One very significant point of difference was the fact that with most existing splicing equipment, the quality of the splice made depends to a very great degree on the skill and dexterity of the operator. Thus the questions arose. Shall we consider the amateur as a typical user to be governed by our standard, or shall we consider only a professional specialist? Those questions have not been completely resolved as yet. The Subcommittee did agree that a standard was needed and that continuing work would be required to obtain a satisfactory answer. Possibly the best solution is to eliminate this human variable entirely with an automatic splicing machine.

The new proposal for silent film is a simplification of the Z22.24-1941 Standard brought into line with the 0.070-in. maximum recommendation. Fig. 2 shows dimensioning practice of Z22.24-1941 on the left and, although not shown, the new silent splice proposal has the same dimensions and is presented in the same manner as the new sound splice proposal shown in Fig. 4, except that the curved splice is not used with silent film.

Fig. 2 shows also the dimensioning practice of Z22.25-1941, Fig. 3 shows the Z52.20 War Standard, and Fig. 4 shows the new proposal.

This new proposal for sound film likewise represents a simplification of the earlier standards in line with the maximum width concept of the Z52.20 War Standard.

At the meeting of the Standards Committee held on February 20, 1946, the recommendations of the Subcommittee were reviewed. It was agreed that consideration of the new proposal as a standard would be premature because the War Standard had not been in effect sufficiently long to test its value satisfactorily. It was agreed that—

(*a*) The American Standards Z22.24 and Z22.25 should be rescinded,

(*b*) The SMPE shall adopt the Subcommittee recommendation for a one-year trial period before final approval,

(*c*) The new proposal shall be published in accordance with (*b*) above, and

(*d*) The new proposal shall be withheld from submittal to the United Nations Standards Coordinating Committee at this time.

Present Status.—As matters now stand, the new proposal, Fig. 4, is published here for trial. All concerned are certain, however,

that the trial period will bring out many pertinent facts about splices that have not been previously submitted for standards consideration. One point under discussion is the relative desirability of the 0.070-in. splice compared with the 0.100-in. splice. Fig. 1, as mentioned previously, shows the relative encroachment of these splices upon the projector aperture. As you will note in the illustration, not even the 0.070-in. splice made under "ideal conditions" with symmetrical overlap in the lap joint and with that much-desired but rarely-realized symmetrical placement of the picture image with respect to the sprocket holes on the film will provide zero encroachment upon the projector aperture area. And note, too, that the "ideal condition" is the best, not the worst, to be expected within present standard limits. There is plenty of room for an enterprising designer to make a splicing machine that will provide a strong splice that does not encroach upon the picture aperture area.

In reviewing the splice problem, let us remember that all splices previously discussed are of the lap-joint type. Before the Society a short time ago came a suggestion for a butt joint with scotch tape overlay for 35-mm work prints—for the purpose of simplified editing. You will observe that your author regarded this use of splices as one of specialized nature. Sixteen-millimeter films are customarily edited in a manner different from 35-mm films; this splicing method may not be applicable.

In Subcommittee discussion, the question was raised as to whether emulsion position of the leading and trailing film edges should be considered or specified. As the whole subject of emulsion position is still open, it was considered pointless to indicate it in connection with splices until the more general problem of emulsion position has been considered further. The broad question of 16-mm emulsion position was discussed by the author in 1942.[4] Despite the absence of any mention of emulsion position, it is considered good practice to make a lap joint with the emulsion side of one piece of film cemented to the base side of the other piece of film to be joined. In this manner the same side is up on both pieces of film.

The location of the leading and trailing edges of the film has not been specified. Many projectors will run film either in the forward direction or in the backward direction. Although some machines for sound will run in only the forward direction, manufacturers have so far indicated no preference.

We have suggested a symmetrical splice as the illustration of the

new proposal shows. Some laboratories that make the Griswold nonsymmetrical negative splice in release prints do not feel that the symmetrical splice is most desirable. Your Subcommittee is anxious to obtain for the record the whys and wherefores that explain their position.

The lowly splice is one of the biggest little things in motion pictures. Now is the time to give it the attention it has long deserved. Four-hundred million feet of 16-mm film a year is too big an item to be ignored even though we may choose to ignore the 2 million or more splices that appear in that footage. We need facts upon which to base our decisions. Many in the Society have the facts. Let us have them available to the Subcommittee where they may be considered instead of remaining buried in unused files. And if we do not have all the facts that we need, let us collect them. The user, the manufacturer, and the laboratory are all waiting for the result. Your Subcommittee is anxious to do its job of establishing the most practicable standards for splices. To paraphrase Al Smith, "—let's put it in the record."

WM. H. OFFENHAUSER JR.
Chairman

[*Ed. Note:* Several comments have already been received from industry users, and readers are encouraged to send in their comments and criticisms direct to W. H. Offenhauser, Jr., Columbia Broadcasting System, 485 Madison Avenue, New York 22, N. Y.

At the end of a year's trial, another report covering the Society's specific recommendations for American Standards will also be published in the JOURNAL.]

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A COMPLETE MOTION PICTURE PRODUCTION PLANT FOR METROPOLITAN NEW YORK*

RALPH B. AUSTRIAN**

Summary.—*A brief description of the plot, buildings, and equipment of New York's newest motion picture studio operated by the RKO-Pathe Corporation.*

For quite some time RKO-Pathe, Inc., has keenly felt the need for its own studio located in metropolitan New York. Such a studio would be used by it for the production of the several series of theater shorts it is currently making, for the increased production of commercial pictures, for the production of documentary pictures, and for the production of other specialized and varied subjects it has long contemplated making.

During the war period the restriction on building or alterations to existing buildings naturally precluded any action toward acquiring either a building or a site. RKO-Pathe's problem was further aggravated by the fact that production demands on it in the above-mentioned fields were greatly expanded. RKO-Pathe's own facilities and such rental facilities as were from time to time available to it were sorely taxed to keep abreast of its production schedule.

The great success the Armed Forces experienced with training films has clearly indicated a tremendous new field for the motion picture. Industry is now calling for films with which to train new workers, demonstrate new products, and sell new products. Another field which is due for an immediate and wide expansion is the production of educational films for use primarily in institutions of learning to supplement the usual pedagogical methods. Finally, the just awakening field of television will require film producing facilities of some magnitude.

All of these factors justified the decision to open and equip a modern studio complete in every detail including a commercial-size

* Presented Oct. 17, 1945, at the Technical Conference in New York.

** President, RKO Television Corporation, New York.

laboratory in metropolitan New York close to the heart of the city. These conditions were hard to meet. The chances of obtaining such a location in New York where realty values are high seemed remote indeed. In addition to wanting the studio to be in the metropolitan district, consideration was given to the need of future expansion, parking facilities, and good transportation. The possibility of finding an existing building available and suitable for such a studio seemed slim, yet a thorough survey was justified in order to save the time required to erect a new building which would require at least one or possibily $1^1/_2$ years.

After a considerable search in the desirable areas, RKO-Pathe was fortunate in locating a building which, with a minimum amount of alterations, exactly suited its requirements, and furthermore the building was vacant and immediately available. It stands on a plot of ground large enough—180 × 200 ft (36,000 sq ft)—to afford room for the necessary supplementary buildings and future extensions to the main building (Fig. 1A and 1B). It is 11 stories high, full brick, reinforced concrete and steel fireproof construction, with double thick walls with air space in between. There are no windows to any of the stages. Each stage has its own individually controlled air-conditioning system. It is 100 per cent sprinkler equipped.

FIG. 1A.

It is located in a district where zoning laws permit the operation of a motion picture studio, the northeast corner of Park Avenue and 106th Street, New York City.

Pathe Film Industries, Inc., whose New York City laboratories are presently located on the premises of Pathe News, 625 Madison Avenue New York, was also satisfied with the facilities the new building

offered and have agreed to expand and incorporate the service laboratory into the new studio.

Main Studio.—A brief description of each floor and floor plans of the main studio building follow.

Basement.—Here will be located the usual heating plant, air-conditioning compressor units, *etc.* All chemicals used in the processing of film will be mixed here.

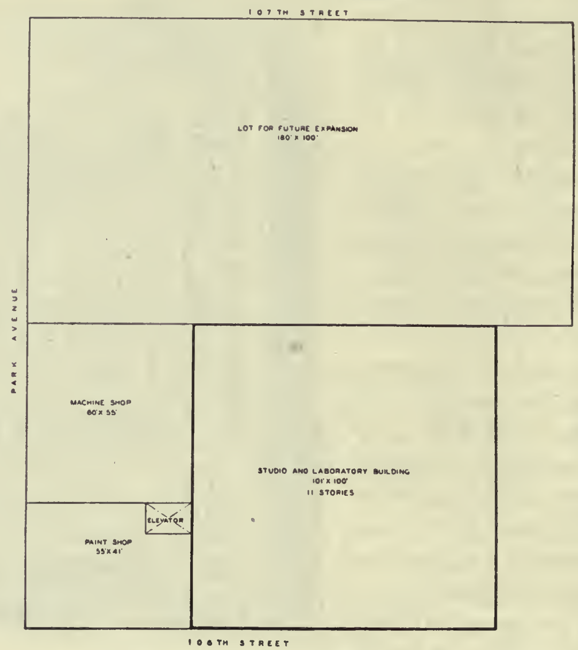

FIG. 1B.

First or Street Level Floor.—Pathe Laboratories is setting up a modern compact service laboratory on the first floor (Fig. 2). The entire laboratory will be finished with salt-glazed tile, and the air-conditioning equipment will be of the latest type using electrostatic filters and automatic controls to achieve maximum cleanliness and uniform conditions throughout the entire area. All of the equipment will be of modern design, with most of it being designed and constructed by Pathe Laboratories, Inc.

Second and Third Floors, Main Studio.—This is the largest shooting stage, measuring approximately 97 × 74 × 32 ft high. This

shooting stage has a wooden floor. All 4 walls and ceiling will be covered with 2 in. rock wool. This stage will be used only for speech recording and, of course, production shooting (Figs. 3 and 4).

Fourth Floor Laboratory, Offices, Vaults, Cutting Rooms, etc.—The entire fourth floor is being devoted to cutting rooms, office space, and screening room for the trade (Fig. 5).

FIG. 2. First floor.

Fifth and Sixth Floors.—Here are located stages *C* and *E* each of which will be 63 ft long × 30 ft wide × 22 ft high (Figs. 6 and 7). Between stages *C* and *E* is a room 51 ft long × 22 ft wide × 22 ft high opening onto both stages, which will be used for the storing of set dressing material, props, electrical equipment, *etc.* These stages will also have wooden floors and will have all walls and ceilings covered with 2-in. rock wool. These 2 studios also will only be used for speech recording and production shooting.

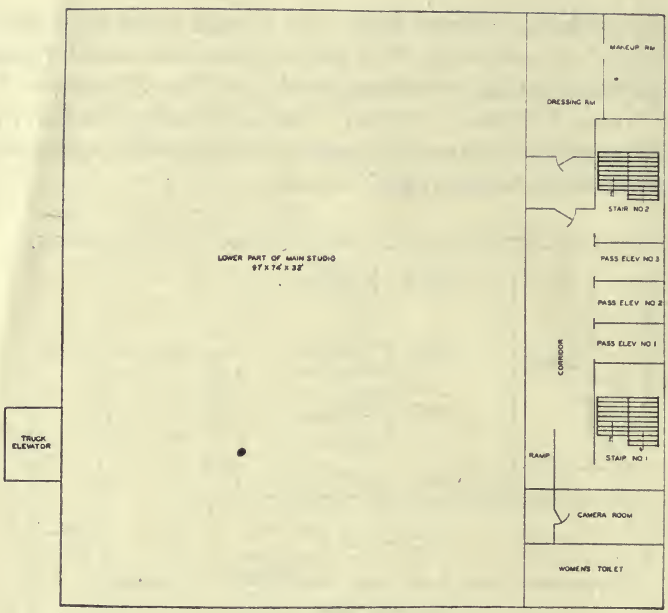

FIG. 3. Second floor.

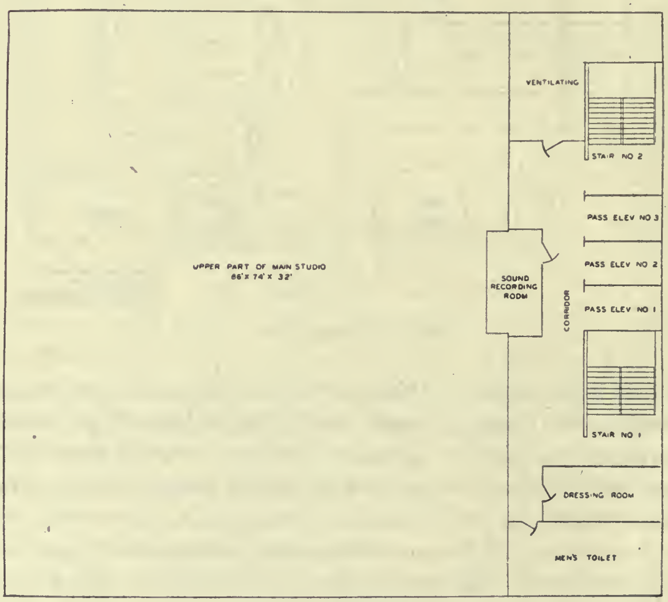

FIG. 4. Third floor.

Seventh and Eighth Floors.—These 2 floors (Figs. 8 and 9) house studio *A*, which is for music scoring and is 63 ft × 52 × 22 ft, and studio *B* which contains a theater seating 70 and this is 50 × 25 × 22 ft. It will also be used for dubbing.

Studio *A* will have the floor covered with linoleum, underneath which is a layer of cork. The south and west walls will be treated

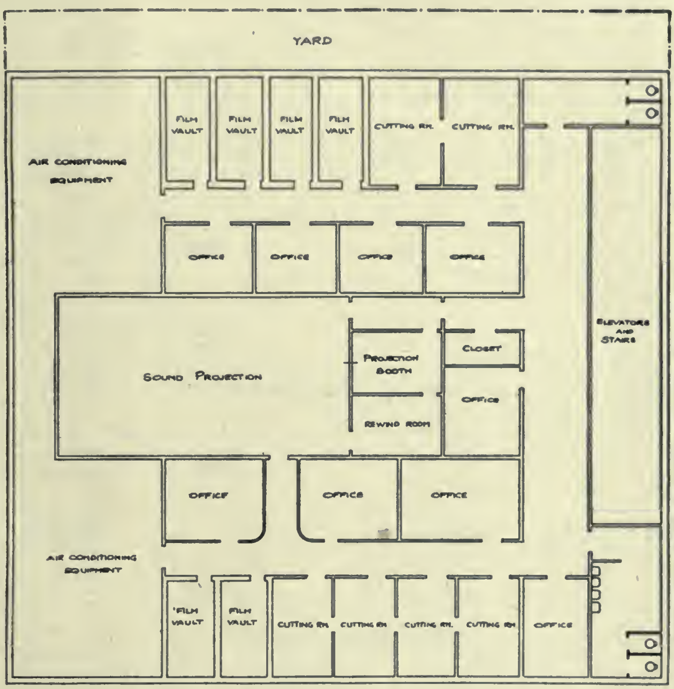

FIG. 5. Fourth floor.

with 1-in. rock wool blanket. Then there will be applied convex plaster panels varying in width from 25 to 45 in. × $21^1/_2$ ft long. These will be applied to the walls in a vertical position, care being taken to scatter the various widths at random to prevent any standing wave characteristics or undesirable reinforcement. Every other panel is removable for acoustic adjustments.

The east and north walls of this studio are also treated with a layer of 1-in. rock wool blanket, and convex plaster panels measuring from 25 to 45 in. × $21^1/_2$ ft long, but on these walls the panels are

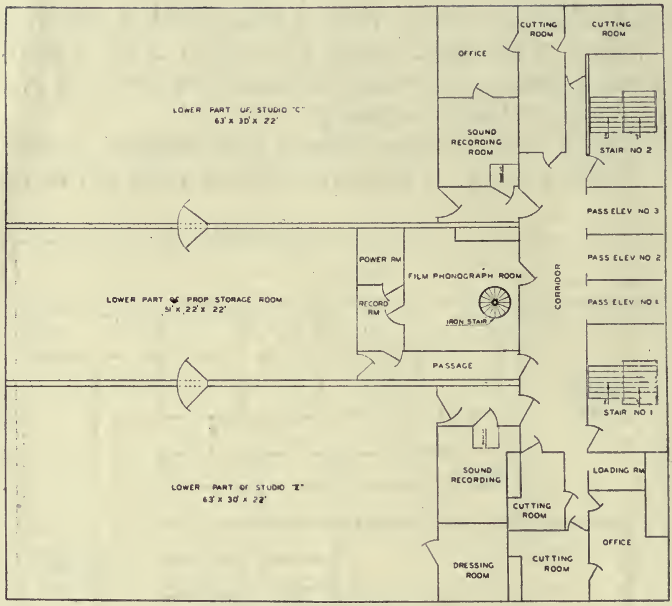

FIG. 6. Fifth floor.

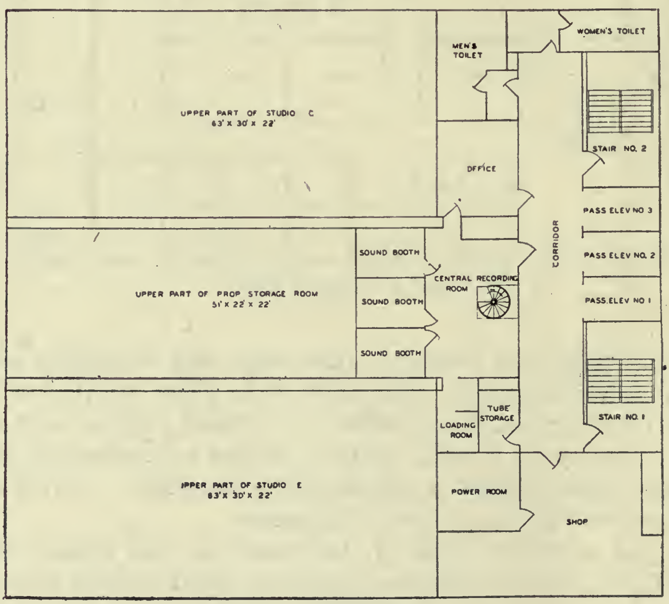

FIG. 7. Sixth floor.

attached in a horizontal position and are not removable. Here again the various widths are applied at random. Adjustable extra full drapes will be hung on the east and north walls over the plaster panels to allow for acoustic corrections. Fifty per cent of the ceiling area will have convex panels applied. Balance of the ceiling area will be exposed rock wool.

Studio *B* is laid out as a combination theater and dubbing room. The ceiling and walls are treated with 1-in. rock wool bats. Over

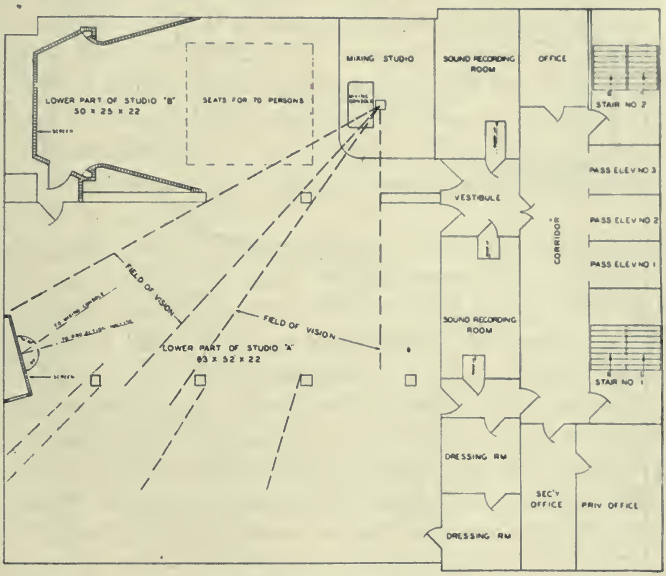

FIG. 8. Seventh floor.

these bats are convex curved plaster panels similar to those provided in Studio *A*. This ceiling will have convex plaster panels covering 75 per cent of the area. The remaining 25 per cent will be exposed rock wool. At the projection screen end of the room adjustable drapes will be hung to provide for acoustic adjustments. The monitor booth for dubbing and rerecording will also be located here. The ninth to eleventh floors are not being equipped at the present time, but they are held in reserve and offer considerably more production space.

Sound Equipment.—RCA sound equipment is being installed throughout. There will be 2 complete studio sound channels. The 2 recorders of these channels may be used to record 2 productions si-

multaneously, or both recorders may be fed in parallel. These 2 recorders are Selsyn driven. There are 6 film phonographs, 2 of which may also be synchronously driven. This is accomplished by having synchronous 3-phase motors as well as Selsyn motors, on the same shaft.

All dialogue mixing will be accomplished by "tea-wagon" mixers which may be plugged into outlets provided on all stages. When using tea-wagons, monitoring will be accomplished by ear plug type

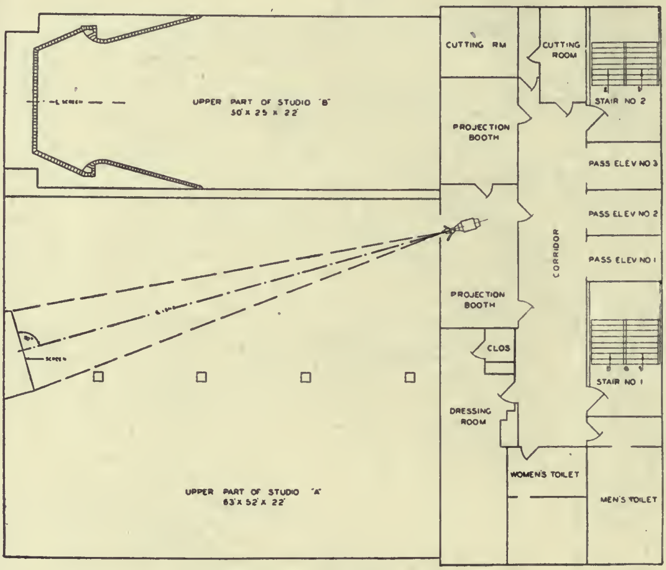

FIG. 9. Eighth floor.

headphones. Monitoring in the scoring and dubbing control rooms will be by means of 2-way standard monitor speakers supplemented if necessary by earphones. There will be 2 projectors located on the upper or eighth floor level. One of these supplies projection for the theater-dubbing stage. The other will be used to project a picture to the scoring stage screen where both the conductor of the orchestra and the scoring mixer can view it through a triple glass window located between the music scoring stage and the rerecording room. These projectors can be driven by either synchronous or Selsyn motors, again by means of having both types of motors mounted on a common shaft. If necessary, these projectors may be interlocked

with each other and with other component parts of the recording system.

On each of the 3 main dialogue shooting stages outlets will be provided for rear screen process projection. The recording console has 8 mixing positions each with rerecording compensators. Compression and variable high-pass filters may be inserted in the voice channel. The 8 mixer positions may be separated and 4 mixers run to each of 2 film recorders.

An interesting constructional detail is the fact that a chorus may be recorded in studio *B* whereas the orchestra is in studio *A*. Each will be acoustically insulated from the other. Each will record on its own channel. Proper balance can easily be obtained by the rerecording process. Both orchestra and singers naturally will be in sight of each other and of the recordist. He will view them through the triple glass window. A monitor loudspeaker will feed the necessary music to the singers.

There are 2 disk recorders driven by synchronous motors. Disk playback is available in either or both music scoring stages and recording room simultaneously. The recording equipment is located in the central plant with a patch field to all studios. Below this "recording central" and connected by a spiral stairwell are located the 6 film phonographs. The recording channels are extremely flexible and will permit disk to film, film to film, film to disk, and disk to disk recording. One portable truck-mounted recording channel will also be available for location shooting. This plant of course will provide RKO Television Corporation with complete eastern production facilities.

ALUMINUM AND CHROMIUM AS GELATIN HARDENERS*

H. L. BAUMBACH AND H. E. GAUSMAN**

Summary.—*The hardening action of aluminum and chromium upon gelatin is explained on the basis of the formation of chemical compounds between the metal ionr and gelatin protein molecules. The metal ions must possess a positive charge in ordes that they may combine with the negatively charged carboxyl groups. The factors which affect the degree of combination are discussed in detail for both aluminum and chromium, the most important being the pH values of the solutions and the presence of competing anions.*

Aluminum fixing baths harden at pH values between 3.5 and 6.0, with the pH of maximum hardening dependent upon the complexing anions that are present. Data are presented that permit selection of the most suitable formulas that can be used under given operating conditions.

Ion migration experiments and other tests are detailed which indicate that chromium fixing baths lose their active hardening properties when the charge on the complex chromium molecules becomes zero or negative. Combination of positively charged chromium and gelatin carboxyl groups is relatively independent of chromium concentration. Complex chromium molecules of zero charge are lightly held by the gelaatin and cause hardening only during and following the drying of the gel.

Chromium fixing baths harden gelatin at pH values from 3 to 6, with the pH of maximum hardening depending upon the sulfite-to-chromium-molal ratio and the age of the solution. Bisulfite ions form complex ions with chromium and increase the rate of hydrolysis of the chromium ions, thereby tending to cause loss of the hardening properties of the solutions with age. By limiting the pH to 4.0 and using a molal ratio of sulfite to chromium less than 2:1, the active hardening properties of a chromium fixing bath are at least partially retained. Other conditions are presented under which the hardening properties are also maintained.

Hypo and silver are retained in washed films by both aluminum and chromium if the complex metal molecules still possess a positive charge after combination with the gelatin occurs. The pH values of the solutions and the presence of complex-forming anions are factors which influence the formation of the desired monovalent complex metal ions.

Introduction.—Chromium and aluminum are commonly used in photographic fixing baths to permit safe handling of the unhardened photographic film during and following processing. The water-absorptive qualities of gelatin are decreased as a result of the harden-

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** West Coast Laboratory, Paramount Pictures, Inc., Hollywood.

ing process and the emulsion is toughened to such an extent that it is less readily scratched or torn while it is wet. After the hardened film has been dried, it is less apt to show handling marks and it is somewhat less susceptible to scratching.

The literature is obscure and often contradictory regarding the factors which affect the hardening qualities of aluminum and chromium, and the chemistry of the processes that are involved are but little understood. The baths that have been recommended are primarily designed to maintain their hardening properties during the normal fixing life of the bath, with a minimum amount of chemical control. The use of continuous electrolytic silver recovery and the necessity for stopping the developing action uniformly have extended the useful life of fixing baths considerably, by offering control over the silver concentration and the *p*H of the bath. It has become possible to operate a fixing bath with a measure of continuous replenishment and to maintain its important functions at constant values; consequently, it has become important that the factors affecting the behavior of the hardening agents within the solution be determined.

In recent years the tendency has been toward the use of aluminum rather than chromium as a hardener for motion picture work, because of the greater stability of aluminum fixing baths and less need for careful control. Chrome-alum fixing baths have tended to lose their hardening characteristics with age and to precipitate an objectionable sludge which deposits on the film. Moreover, they must be subjected to more rigid chemical control in order to function satisfactorily. Probably the preference for aluminum has been influenced somewhat by the better understanding of the use of this substance as contrasted to the rather erratic and complicated behavior of chromium, but more information is needed on the chemistry of both aluminum and chromium before their relative merits can be evaluated.

The single factor that affects the action of the hardening agents to the greatest degree is the *p*H of the solution, and since, with chemical control, it is possible to maintain the fixing bath at almost any desired *p*H value, it is important to determine the influence of the *p*H upon the hardening properties of aluminum and chromium. If the *p*H is controlled in a bath, the quantity and nature of developer that is carried into the fixing bath lose their significance in regard to indicating the condition of the bath, and chemical and physical methods must be used to determine the ingredients that should be added, and the replenishment procedure.

The conception that film hardening is caused by the simple precipitation of basic salts of aluminum or chromium within the cellular structure of the gelatin leaves much to be desired in terms of explaining the action of these substances, since gelatin is frequently hardened under conditions where precipitation will not take place. Moreover, if this explanation were correct, hardening should depend primarily upon the quantity of alkali carried by the film as it enters the fixing bath, and hardening should be at a maximum when the fixing bath is closest to the *p*H of precipitation. Actually, neither of these factors is significant so far as the degree of hardening is concerned. It is quite improbable that the formation of an insoluble hydroxide of aluminum or chromium bears any more than incidental relationship to the hardening process.

The solution chemistry of aluminum and chromium is complex, but it is only by means of a discussion of the solution reactions of these substances in line with the modern principles of atomic structure that any logical explanation of their hardening properties can be made. With the knowledge of the chemical reactions that are involved, the hardening action of solutions of these substances can be controlled.

Aluminum Fixing Baths.—Aluminum is an amphoteric element capable of existing in solution in both acid and basic forms. In solutions of low *p*H, aluminum possesses a positive charge and enters into reactions typical of these ions, with the formation of such compounds as aluminum chloride, $AlCl_3 \cdot 6H_2O$, and aluminum sulfate, $Al_2(SO_4)_3 \cdot 9H_2O$. In solutions of high *p*H, aluminum is present as a negative ion with the formation of compounds such as sodium aluminate, $NaAlO_2$.

The aluminate form has been used as an addition agent to photographic developers of special properties, but aluminum is commonly used in fixing baths in its acid form. Aluminum forms soluble compounds with the ingredients that are needed in fixing baths and hence its use as a hardener does not restrict the normal fixing action of the bath. Its thiosulfate, bisulfite, sulfate, bromide, iodide, chloride, acetate, and citrate are all sufficiently soluble and do not cause precipitation within the bath. However, certain basic salts of many of the above ions or of the ortho phosphate ion are not appreciably soluble, and the precipitation of these compounds limits the usefulness of the fixing bath both by removing aluminum ions from solution, thereby reducing the hardening action, and by acting as a source of scum and dirt that collects on the surface of the film. Basic alumi-

num salts tend to form at pH values as low as 3.5, so that it is advisable to modify the fixing bath constituents by the addition of compounds that tend to form more soluble basic salts in order to permit operation of fixing baths at higher pH values.

Many substances will act in the capacity to form more soluble basic salts, and most of them constitute organic ions that form slightly dissociated complex ions with aluminum. Some of the substances that have been suggested as complexing agents are shown in Fig. 1, which is a plot of the pH of precipitation (sludging) of basic aluminum

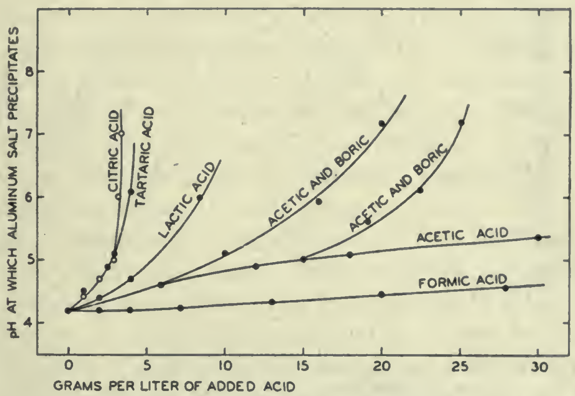

FIG. 1. The influence of concentration of various organic acids or their salts upon the pH at which an aluminum fixing bath sludges. Each liter of the bath contains 350 grams of hypo, 15 grams of anhydrous sodium sulfite, and 25 grams of potassium aluminum alum, in addition to the added complexing acid.

compounds from a typical fixing bath, against weights of complexing agents. Thus, a fixing bath which contains no complexing agents sludges at a pH of 4.2, the increase from the value of 3.5 being the result of the slight complexing action of thiosulfate and bisulfite. The pH of precipitation is not appreciably raised by further addition of these ingredients. Of the complexing agents that are shown, it is evident that citric acid is the most effective material, by weight, that can be used for this purpose; addition of as little as 4 grams per liter of this substance to the given formula prevents immediate precipitation of aluminum at any acid pH. Acetic acid is much less effective as an addition agent, and it is apparent that as much as 15 grams per liter of the acid must be present to prevent precipitation up to a pH of

5.0. The addition of boric acid, as was suggested by Russell and Crabtree,[1] increases the complexing action of acetic acid but it is relatively ineffective if used alone; its effect is shown for 2 concentrations of acetic acid, 6 grams per liter and 15 grams per liter.

When it is possible to control the *p*H of a fixing bath, the buffering capacity of the bath becomes relatively unimportant and it is feasible

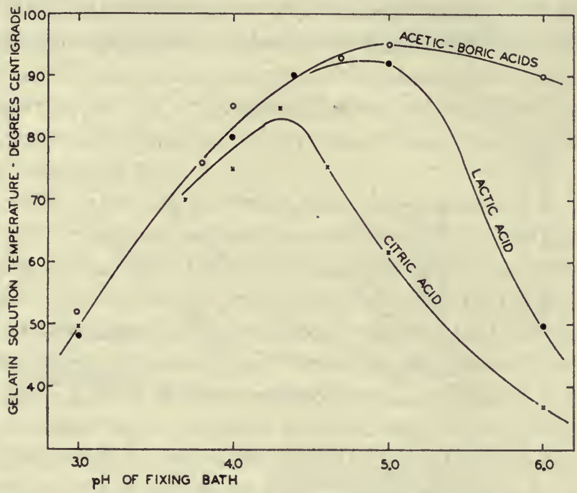

FIG. 2. The melting point values of the gelatin layer of picture negative film that is developed (10 min in negative developer), rinsed (15 sec), and fixed (10 min) in aluminum baths containing various complexing acids. Separate baths are regulated at *p*H values from 3 to 6. The baths contain 350 grams per liter of hypo, 15 grams per liter of sodium sulfite, 25 grams per liter of potassium aluminum alum and the acid. Only enough of the complexing acid is added to prevent sludging to *p*H 6 (Fig. 1), which is 3.4 grams per liter of citric acid, 9 grams per liter of lactic acid, and 15 grams per liter of acetic acid with 7.5 grams per liter of boric acid.

to use any substance with suitable complexing action which will form a compound with aluminum that is soluble at the desired *p*H value.

The most important single factor that affects the hardening action of aluminum is the *p*H of the fixing bath. Fig. 2 presents data of the hardening action of aluminum upon the gelatin of typical negative film in fixing baths containing various acids as complexing agents. The quantity of the acid used was not selected on a weight basis, but rather upon the amount that would complex the aluminum to the

same pH of precipitation; the amounts were selected such that sludging would occur at an approximate pH of 6. As the pH increases from a value of 3, the hardening action is independent of the nature of the complexing ion until the pH exceeds 4.5 when citrate ion interferes with the hardening action. Lactate ion does not interfere until the pH exceeds 5.0, while, if acetic and boric acids are the complexing agents, hardening continues to be good to the pH of precipitation. Increasing the concentration of any of the complexing agents raises the pH of sludging and also decreases the pH at which hardening is impaired. In these experiments the degree of hardening was determined by measuring the melting point (solution temperature) of unhardened negative film as suggested by Crabtree and Hartt.[2]

If operation of a fixing bath at a pH of 4.0 is desired and if the alkali that is introduced by developer is neutralized by the addition of any noncomplexing acid, such as sulfuric or bisulfite, equal hardening will be produced with any of the acids tested, provided that complexing of the aluminum is carried to the same extent.

The Solution Chemistry of Aluminum and Gelatin Hardening.—When salts are dissolved in water, there should be no greater tendency for solution to occur than there is in the air, if it were not for the attractive forces possessed by the water molecules for the ions that form the salt. The water molecules are polar particles that possess free electron pairs by means of which attachment can be made to ions or ionic groups. The surrounding of the ions by water molecules changes the identity of the ions sufficiently to permit them to overcome the electrostatic forces which hold them within the crystal lattice. The energy that is required to separate such a large charge as that on Al^{+++} from negative ions is so great that the solubility of this ion in water can only be accounted for on the basis of ion hydration.

Thus, it has been established that aluminum exists in water solution in the form of a hydrated ion where the number of associated water molecules is at least equal to the maximum coordination number of aluminum or, diagrammatically, in the form $Al(H_2O)_6^{+++}$. At least 6 water molecules surround each aluminum ion in a definite directed manner, and the molecules are said to be coordinated through the sharing of electron pairs between the oxygen atoms and the vacant energy levels of the aluminum atom. The strong positive charge on the central aluminum atom tends to repel protons from the coordinated water molecules and the protons are in turn coordinated with

other water molecules; hence, the hydrated aluminum ion possesses acid properties and becomes reduced in net charge upon neutralization.

The type of reaction that is involved is diagrammed in reaction (*1*).

$$Al(H_2O)_6^{+++} + H_2O = Al(H_2O)_5(OH)^{++} + H_3O^+. \qquad (1)$$

The net charge on the aluminum ion is reduced by one and the hydronium ion which is formed accounts for the acid properties of the aluminum.

Aluminum ion first shows its acid properties at a *p*H of 3 and, in all, functions as a tribasic acid, since each mole of aluminum requires 3 moles of sodium hydroxide for neutralization. As the *p*H of the solution increases from 3, additional release of protons from coordinated water molecules occurs, leading to the reactions shown in (*2*) and (*3*).

$$Al(H_2O)_5(OH)^{++} + H_2O = Al(H_2O)_4(OH)_2^+ + H_3O^+. \qquad (2)$$

$$Al(H_2O)_4(OH)_2^+ + H_2O = Al(H_2O)_3(OH)_3 + H_3O^+. \qquad (3)$$

After the addition of 3 equivalents of alkali, the reactions have practically gone to completion with the formation of uncharged $Al(H_2O)_3(OH)_3$, which is insoluble and precipitates from solution.

The titration curve for aluminum with alkali (Fig. 3) has no breaks in it, which indicates that all 3 reactions are in rapid equilibrium with each other and that the ionization constants of the 3 acid ions are close together. The tendency is toward the formation of a mixture of the ions, with the *p*H determining the ion that is present in the greatest concentration. While the first evidence of acid properties (reaction (*1*)) occurs at a *p*H of 3, the first precipitation of a portion of the $Al(H_2O)_3(OH)_3$ is observed at a *p*H of 3.5 and occurs before the first equivalent of alkali has been added.

With aluminum, chromium, zinc, and other amphoteric elements, this type of reaction progresses with the formation of soluble negatively charged ions called aluminates, chromiates, zincates, *etc.*, in a manner diagrammed by reaction (*4*).

$$Al(H_2O)_3(OH)_3 + H_2O = Al(H_2O)_2(OH)_4^- + H_3O^+. \qquad (4)$$

The net positive charge on the aluminum ion decreases as the *p*H increases, becoming negative in alkaline solutions.

The nature of the aluminum ion is altered by the loss of protons or, in other words, by substitution of hydroxyl groups for water molecules. Greater modification occurs when certain other groups become

substituted; the only necessary qualification for coordination being that the groups must possess at least one free pair of electrons that can assume energy levels in the aluminum atom. If the *p*H is such that free acetate ions, for example, can exist in solution with hydrated aluminum ions, the acetate ions will tend to replace coordinated groups as the concentration of acetate ions increases, giving the new aluminum ion different properties (*i. e.*, greater solubility). Hence, such ions as $Al(H_2O)_4(OH)(Ac)^+$ or $Al(H_2O)_4(OH)(HSO_3)^+$ exist in a fixing bath.

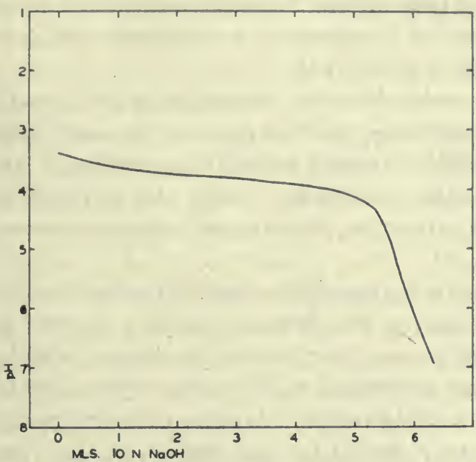

FIG. 3. The titration of 12.5 grams of potassium aluminum alum in 500 milliliters of water with approximately 10 *N* sodium hydroxide. The 3 acid equivalents of aluminum are nearly equal and are active between the *p*H values of 3.5 and 7.

Citrate ions are even more striking in their ability to coordinate with aluminum, as evidenced by the complete solubility of aluminum at all *p*H values when the molal ratio of citrate to aluminum exceeds 1:3 (Fig. 1). Citric acid is a tribasic acid, and one mole of the acid can accommodate 3 moles of aluminum.

Tartaric acid is a dibasic acid and, similarly, forms a soluble coordination complex with aluminum ion when present in a molal ratio greater than 1:2. The evidence is that coordination occurs with the aluminum ion through the supplying of an electron pair by the oxygen atom of the carboxyl group.

Fresh acid solutions of citric acid and aluminum in a molal ratio of 1:3 that are quickly made alkaline show complete solubility at all *p*H values. However, if the solution is allowed to stand at a *p*H near 7, slow precipitation of some of the aluminum takes place as hydroxyl groups replace carboxyl groups; the solution slowly becomes more acid. In this respect the behavior of aluminum closely parallels that of chromium which will be discussed later.

The nature of the organic anion determines the completeness with which hydroxyl groups can be replaced and coordination can occur, so that, while citrates and tartrates coordinate readily, relatively large concentrations of ions such as formate, acetate and propionate must be present to convert aluminum ions completely and prevent precipitation of aluminum at any *p*H.

The protein molecules that comprise gelatin contain carboxyl groups which possess free electron pairs as the acid groups dissociate, and it is reasonable that such groups can coordinate with aluminum ions under favorable conditions. Since the carboxyl groups of the gelatin are fixed in position, the attached aluminum ions may migrate only within the gel.

The requirements for favorable coordination of aluminum and gelatin carboxyl groups involve, first, the absence of other groups within the solution with greater coordination tendencies, which explains the loss of hardening properties which occurs when citrate or tartrate ions are present in the solution. If other carboxyl groups are present (*i. e.*, acetate), they should be mild enough in their action and low enough in concentration that the gelatin carboxyl groups can compete with them for the aluminum.

The second requirement for coordination involves the presence of the free electron pairs on the oxygen atoms of the gelatin carboxyl groups. The acid properties of gelatin are mild, which is to say that the ionization constants are low. The isoelectric point of photographic gelatin occurs at a *p*H of 4.9, which is the *p*H at which the acid and basic properties are equal in magnitude; it is not the minimum *p*H at which carboxyl groups can ionize, and some gelatin carboxyl groups can probably exist in ionic form at *p*H values below 3. As the gelatin is made more alkaline from a *p*H of 3, greater numbers of carboxyl groups will become ionized with practically complete ionization occurring at *p*H values above 7; thus the conditions for coordinating carboxyl groups become increasingly favorable as the *p*H increases from 3 to 7.

The third requirement for coordination involves the nature of the charge on the complex aluminum ion. If the aluminum ion is negatively charged (aluminate), it will tend to be repelled by the similar charge of the gelatin carboxyl ion and coordination cannot be expected to occur. Similarly, a net charge on the aluminum ion of zero will permit no more than accidental coordination. In order for aluminum ions to be attracted to the negatively charged gelatin ions it is necessary that the aluminum be positive in charge, which can only be the case at pH values somewhat less than 7. The net result of the second and third requirements is the type of hardening curve with respect to pH that appears for acetic and boric acids in Fig. 2. Evidence of the first requirement not being met is shown by the decrease in hardening that occurs at the higher pH values in solutions containing citrate and lactate ions.

As the pH decreases, the net positive charge on the aluminum ion increases, and if coordination does occur at pH values as low as 4, for example, the net charge on the coordinated aluminum ion will still be positive and the complex molecule will still be free to accept other negatively charged ions such as acetate, hydroxyl or silver thiosulfate groups, the last of which is of great importance in the retention of hypo and silver during washing and will be discussed later.

When gelatin becomes hardened, it is characterized by a lower degree of water absorption at a given temperature, or, to express the same thing in a different way, there is an increase in the temperature at which gelatin absorbs sufficient water to cause disruption of the attractive forces that permit an oriented structure to the gel. Ordinary unhardened gelatin swells when placed in water, to an extent that depends primarily upon the pH of the solution. The swelling tendency increases at pH values on both sides of the isoelectric point and follows, in a general way, the increased ionization. Since water molecules are polar, they can readily become attached only to other polar groups, hence the swelling of gelatin arises largely out of the presence of ionic groups on the protein molecules; when these groups are made neutral by coordination with aluminum ions, the tendency for the gelatin to absorb water is reduced.

The problem of preventing the excessive swelling of gelatin during photographic processing is frequently approached in another way; the addition of soluble ionic salts, such as sodium sulfate, to the photographic solutions provides competition for the water molecules that limits the quantity of water that the ionic protein groups may retain.

This type of hardening is described as "temporary," since it disappears when the film is subsequently washed in water. The salts that are formed between aluminum, chromium, iron, and other metal ions and the protein molecules are insoluble in water and such hardening is called "permanent."

Practical Operation of an Aluminum Fixing Bath.—While potassium aluminum alum is usually suggested as the source of aluminum for fixing baths, some economy can be made by using equivalent amounts of other aluminum salts, such as hydrated aluminum chloride or aluminum sulfate, since moderate quantities of ions like potassium, chloride or sulfate are without harmful effect upon the action of the bath.

If the *p*H of the fixing bath is to be held constant, and such must be the case in a motion picture laboratory if the developing action is to be stopped uniformly, choice of a fixing bath formula will depend somewhat upon the *p*H value that is selected for plant operation. From the data of Fig. 1 and for an aluminum alum concentration of 25 grams per liter, it is evident that 15 grams per liter of acetic acid (or its equivalent of sodium acetate) will prevent sludging to a *p*H of 5.0. Since it is not advisable to operate within less than 0.5 *p*H unit of the precipitation point, because of the danger of scum formation in the wash water, the limiting *p*H at which this formula should be operated is probably 4.5. If the *p*H of operation is as low as 4.0, as little as 5 grams per liter of acetic acid should be sufficient. Crabtree, Eaton, and Muehler[3] have demonstrated the advantages of operating an aluminum fixing bath at *p*H values as great as 5.0 to minimize hypo and silver retention; if this is done, it is advisable to add enough boric acid to prevent sludging to a *p*H of 6.

If complexing with boric acid is not carried beyond a *p*H of 6, such a formula will harden well at all usable *p*H values, but it represents a needless use of chemicals for operation at the lower *p*H values. The boric acid-acetic acid fixing bath hardens gelatin poorly at a *p*H of 3 and quite well at *p*H values between 4 and 6 (Fig. 2), with maximum hardening occurring at a *p*H of about 5.

The preparation of aluminum fixing baths is quite simple and the chemicals may be added dry to the solution as it is prepared, provided the agitation is adequate and the ingredients are added in the order of hypo, sodium sulfite, acetic acid (boric acid), and alum. The temperature of the water should be high enough at the start so that the addition of the hypo will result in a normal temperature of use.

The concentration of bisulfite ion will become lower with use, owing to loss of sulfur dioxide, and some means of analysis and replenishment is desired, although the concentration of this substance is not critical in an aluminum bath. It is only necessary to maintain the sulfite concentration at a level high enough to prevent sulfurization under the conditions of use. Replenishment of the bisulfite can equally well be made by addition of sodium bisulfite or sodium sulfite and sulfuric acid. Probably regulation of the *p*H should not be attempted with acetic acid, especially if there is excessive alkali carryover, because too much acetate ion is harmful to the hardening properties of the bath, and because relatively large quantities are needed to produce a small change in *p*H. Sulfate ion is not harmful in the fixing bath and sulfuric acid can be safely added in its concentrated form to the fixing bath, provided agitation is good, the acid is added slowly, and the sulfite concentration is maintained. Plants using electrolytic silver recovery systems usually need little acid to neutralize developer alkali, since acid is liberated at the anodes while silver is formed at the cathodes.

Within their limitations, other acids may be used in aluminum fixing baths with satisfactory results. Formic acid, citric acid, and lactic acid used in the proper quantities as outlined above, and doubtless many other acids not investigated here, can be made to function where control over *p*H is practiced, but there are few advantages to be gained over the use of the economical acetic acid. Citric acid is of particular interest in connection with its influence upon hypo and silver retention and will be mentioned later.

The hardening properties of the aluminum-acetic acid formula do not change with age, as is usually the case with chromium; sulfur is formed in the bath if the *p*H is too low or the sulfite concentration is too low. If the sulfur is filtered off and the condition corrected, use of the bath may be continued. Basic aluminum salts precipitate if complexing is not adequate or the *p*H is too high, but these substances will usually redissolve if the *p*H is lowered. Aluminum fixing baths are easy to prepare and to maintain; they harden well under the proper conditions and are open only to the criticism that they tend to prevent complete removal of hypo and silver during the washing process.

Chromium Fixing Baths.—Chrome-alum fixing baths have been suggested where unusual hardening of the gelatin is desired, such as might be needed under tropical conditions. Since the hardening

and sludging properties of chrome-alum fixing baths become inferior with age, it has been suggested that the solutions should be freshly prepared and discarded when they lose their hardening properties. Such statements as "chrome-alum fixing baths tend to harden the film excessively or not at all" appear in the literature and have tended to discourage the use of chromium for this purpose. Nevertheless,

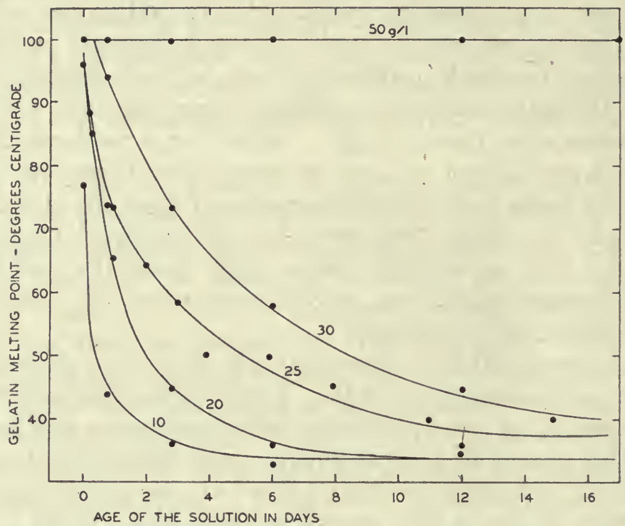

FIG. 4. The melting point values of the gelatin layer of picture negative film that is developed (10 min in negative developer), rinsed (15 sec), and fixed (10 min) in chromium fixing baths containing 350 grams per liter of hypo, 15 grams per liter of sodium sulfite, and various concentrations of chrome alum. The baths are all regulated to *p*H 4.0 by means of sodium hydroxide or sulfuric acid. Loss of hardening properties with age occurs, unless the concentration of chrome alum is high.

chrome-alum fixing baths are used successfully as continuously replenished solutions, producing a moderate degree of hardening and satisfactory general operation.

Like aluminum, chromium does not form insoluble compounds with fixing bath ingredients. Unlike aluminum, chromium does not immediately reach equilibrium with the components of the solutions in which it is placed, and it is quite possible to prepare such solutions in a manner which will require days or even months for an equilibrium to be reached. The typical chrome-alum fixing bath is representative

of just such a condition, and the loss of hardening properties with age represents the reaching of an equilibrium between the added chromium and the ingredients of the fixing bath. Because of the slow reactions involved with chromium, changes that are made within the bath are usually not immediately effective or may not persist on standing.

While the organic carboxylic acids such as acetic and citric acids can be added to chrome-alum fixing baths in moderate concentrations without immediate change in the function of the bath, the loss of hardening proceeds at a rapid rate to reach the new equilibrium condition. Consequently, the use of any organic acid is not advisable in a chrome-alum fixing bath.

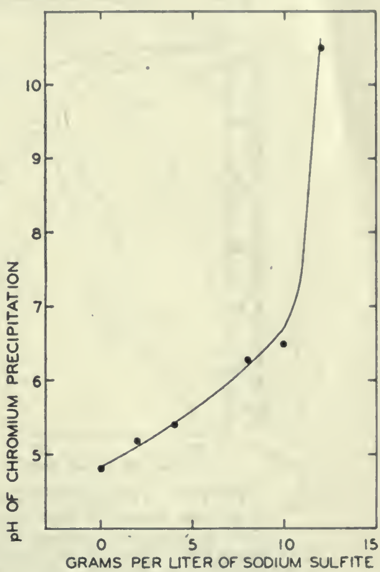

FIG. 5. The effect of concentration of sodium sulfite upon the pH of sludging of a fresh chrome-alum solution (25 grams per liter). Precipitation is prevented in acid solution if the molal ratio of sulfite to chromium exceeds 2:1.

Sulfuric acid is usually recommended for use with chrome-alum fixing baths because the baths prepared with this acid have the greatest stability. It is a strong acid that has little of the desired buffering action characterized by the weak organic acids, and consequently it must be added repeatedly to the bath to neutralize the alkali that is introduced as developer. Sodium sulfite or bisulfite is necessary to prevent sulfurization of the fixing bath and provides most of what little buffering capacity is possessed by the bath. However, as will be shown later, much of the bisulfite is not free to act either as a buffer or to prevent sulfurization.

In a study of the effect of chromium concentration upon film hardening, a series of chrome-alum fixing baths was prepared and controlled to a pH of 4.0. The degree of gelatin hardening was determined for each of the samples over a period of time, producing the results that are shown in Fig. 4. It is evident that, as the concentra-

tion of chromium is increased in this solution, the rate at which the solution loses its hardening properties decreases until, at a concentration of 50 grams per liter, no loss of hardening occurred in 17 days. Gelatin solution temperatures are not shown in excess of 100 C, so that this part of the curve is missing. However, the lack of aging cannot be accounted for on the basis of concentration alone, since a drop in the hardening curve for the 50 grams per liter concentration

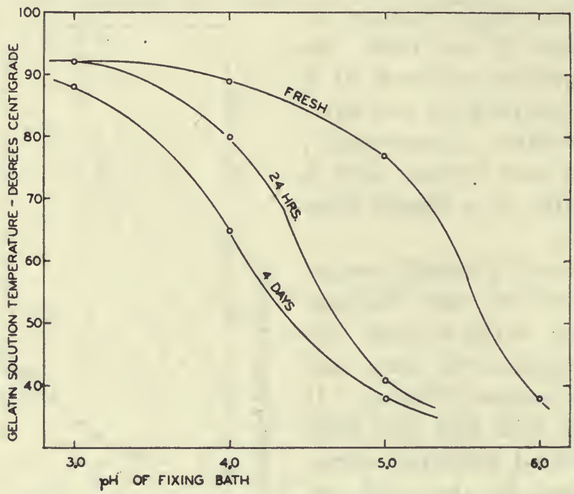

FIG. 6. The melting point values of the gelatin layer of picture negative film that is developed (10 min in negative developer), rinsed (15 sec), and fixed (10 min) in chromium fixing baths containing 350 grams per liter of hypo, 17.5 grams per liter of sodium sulfite, and 25 grams per liter of chrome alum. Separate baths are controlled to *p*H values from 3 to 6. The molal ratio of sulfite to chromium is 3:1.

would have been expected in a few days. In addition to maintaining its hardening properties, the sample with 50 grams of chrome alum showed sulfurization after a week of storage at a *p*H of 4.0, in spite of the high concentration of sulfite in the solution.

The influence of the concentration of chromium upon the loss of hardening properties with age and upon sulfurization suggests that the relative balance between chromium and bisulfite is important. Accordingly, the effect of sulfite concentration upon the *p*H of precipitation of chromium was investigated for a solution of thiosulfate and chrome alum; the results of these experiments are shown in Fig.

5. Here it is apparent that as the concentration of sulfite is increased the solubility of the basic chromium salt also increases, and when the molal ratio of sulfite to chromium exceeds 2:1, no precipitation of chromium occurs at any acid *p*H.

Since the molal ratio of sulfite to chromium is thus of importance in a chromium fixing bath, the degree of hardening as a function of *p*H was studied at various molal ratios from 1:1 to 3:1 with the results

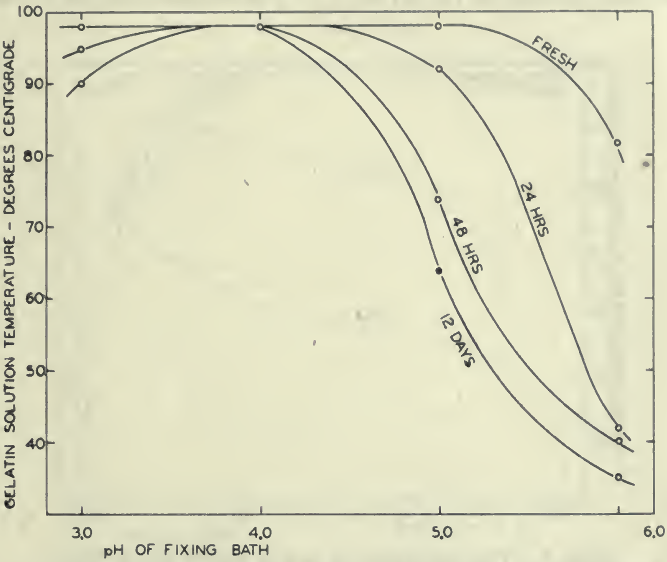

FIG. 7. The melting point values of the gelatin layer of picture negative film that is developed (10 min in negative developer), rinsed (15 sec), and fixed (10 min) in chromium fixing baths containing 350 grams per liter of hypo, 9 grams per liter of sodium sulfite, and 25 grams per liter of chrome alum. Separate baths are controlled to *p*H values from 3 to 6. The molal ratio of sulfite to chromium is 1.5:1.

shown in Figs. 6 to 8. The loss of hardening properties with age and the *p*H values at which hardening occurs are very definitely related to the molal ratio of sulfite to chromium. The chrome-alum fixing bath shown in Fig. 6 had a sulfite-to-chromium-molal ratio of 3:1 and is representative of the chrome-alum baths that have been recommended for use. The fresh bath shows moderately good hardening at a *p*H of 3.0 with decreasing hardening as the *p*H increases, practically no hardening being produced at a *p*H as high as 6. Upon standing for a period of time, the bath loses its hardening properties

more rapidly as the pH is increased, the greatest stability being observed at a pH of 3.0. This bath does not sulfurize or sludge upon standing, but evolves considerable sulfur dioxide.

When the molal ratio of sulfite to chromium is reduced to 3:2, and the same series of tests run (Fig. 7), it is observed that the fresh bath hardens somewhat better and does not show a drop in hardening properties until the pH is in excess of 5. As the solutions aged, loss of hardening properties occurred at all pH values except 4.0 and was

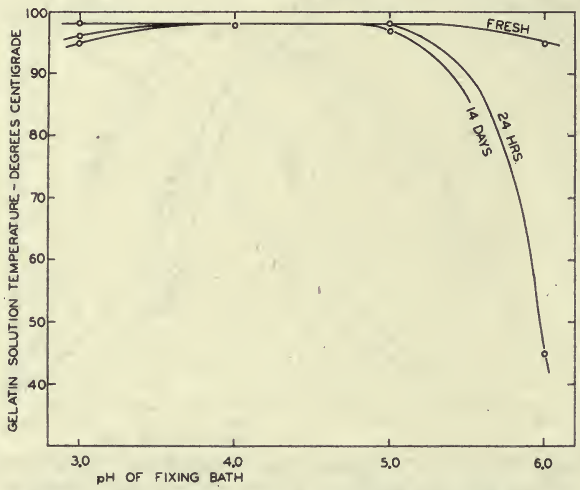

FIG. 8. The melting point values of the gelatin layer of picture negative film that is developed (10 min), rinsed (15 sec), and fixed (10 min) in chromium fixing baths containing 350 grams per liter of hypo, 6 grams per liter of sodium sulfite, and 25 grams per liter of chrome alum. Separate baths are controlled to pH values from 3 to 6. The molal ratio of sulfite to chromium is 1:1.

most rapid at higher pH values. The bath at pH 3.0 sulfurized and that at pH 6.0 precipitated chromium in a few hours, but those at pH values of 4.0 and 5.0 remained free of precipitate for the duration of the tests.

A fresh chrome-alum bath with the ratio of sulfite to chromium of 1:1 hardens gelatin well at all pH values between 3 and 6 (Fig. 8) and loss of hardening properties occurs rapidly at pH values over 5. Sulfurization occurs extremely rapidly at a pH of 3.0 and in a few hours at pH 4.0. Chromium precipitates in a few hours from the

bath at pH 6.0 and only the bath at pH 5.0 remained clear for the duration of the tests.

This series of tests shows definitely that the molal ratio of sulfite to chromium is of the greatest importance in the satisfactory operation of a chrome-alum fixing bath. It is unfortunate that chromium and sulfite form complex compounds, since the necessity of adding sulfite to prevent sulfurization must be weighed against the resulting loss in hardening properties.

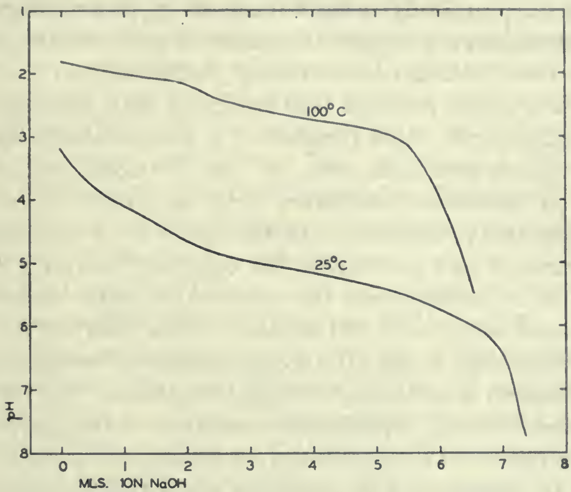

FIG. 9. Titration of 12.5 grams of chrome alum in 500 milliliters of water with 10 N sodium hydroxide. The full acid properties of chromium are not immediately evident at room temperature and there is greater separation between the 3 acid equivalents of chromium than there is for aluminum.

The aged chrome-alum fixing bath with a sulfite-to-chromium ratio of 3:1 shows a reduction in the degree of hardening with increased washing after development, while with the bath of 1:1 ratio and the aluminum baths the amount of washing after development has no effect upon the degree of hardening.

Chromium is a colored ion and when combination with gelatin occurs, the film is stained slightly, by an amount which is proportional to the degree of hardening.

The Solution Chemistry of Chromium and Gelatin Hardening.—Like aluminum, trivalent chromium exists in water solution as a

coordinated ion of the type $Cr(H_2O)_6^{+++}$, which has properties that are very similar to those of the corresponding aluminum ion. Thus, the hydrated ion has marked acid properties and it enters into a series of reactions that is identical with reactions (*1*) to (*4*) that were discussed under aluminum. Somewhat higher *p*H values are needed, however, to form the corresponding chromiate ion.

Perhaps the most striking difference between the behavior of trivalent chromium and that of aluminum lies in the comparison of the reaction rates of the 2 substances. The coordination reactions of aluminum are practically instantaneous at room temperature, while those of chromium are so slow that days or even months may be required for the chromium ions to reach equilibrium in the solutions. The type of sluggish reaction that is typical with chromium is illustrated by the simple, rapid titration of a chrome-alum solution with standard sodium hydroxide (Fig. 9). In this titration at room temperature, an equilibrium condition is never permitted to occur and the complete acid properties of the chromium are not evident. During the course of such a titration, the tendency is always present for the slow loss of protons from the coordinated water molecules, with the resulting drift to lower *p*H values. If the titration is performed stepwise, with 24-hr lapses after every addition of sodium hydroxide, or if the titration is performed at high temperature (80–100 C), there is opportunity for the equilibrium condition to be approached and the acid properties of the chromium are much more pronounced, with a break in the titration curve appearing at the first equivalence point. (The hot titration shown in Fig. 9 was performed by adding the hydroxide to the chrome alum solution, which was heated to 100 C. Small samples of the solution were cooled to 25 deg for *p*H measurement and returned to the bulk solution.) It is apparent that the equilibrium acid properties of chromium are greater than those of aluminum and that the first step in the hydrolysis is especially strong. The conductimetric measurements of Kuntzel, Riess, and Konigfeld[4] also indicate this spread in ionization constants. Even quite acid solutions of chromium (*p*H 3–4) will thus contain the hydrolyzed chromium ion, when an equilibrium has been reached.

The sluggish nature of chromium in reaching an equilibrium with its solutions greatly complicates the study of the properties of such solutions, since they undergo a change with time and the end products are usually quite different from the starting materials. The fact that chromium fixing baths tend to lose their hardening properties with

age is suggestive that the solutions are not initially compounded to form a satisfactory equilibrium condition.

Chromium differs also from aluminum in its much greater tendency to form coordination complexes with the simple anions, such as sulfate, sulfite, and the halides. Definite chromium chloride complexes exist, for example, where various amounts of the chloride are directly coordinated to the chromium and cannot be precipitated with silver nitrate. Thus chromium chloride can be prepared in forms ranging from $Na_3(CrCl_6)$ to $Cr(H_2O)_6Cl_3$, where the charge on the complex chromium ion ranges from -3 to $+3$. Even a water solution of chrome alum may contain a part of the sulfate coordinated with the chromium that cannot be precipitated with barium ion. Such coordination complex ions are relatively common with chromium and they may persist for some time when added to solutions that are unfavorable for their formation. The coordination chemistry of chromium has been discussed in considerable detail by Friedman.[5]

Chrome alum is a double sulfate of chromium and potassium; the violet colored crystals dissolve in water to give a violet solution that is colored by the $Cr(H_2O)_6^{+++}$ ion. Upon standing, the acid properties become increasingly evident as the green $Cr(H_2O)_5(OH)^{++}$ ion forms and the solution becomes more gray in color. The equilibrium concentrations of the 2 ions are influenced by the *p*H and the temperature of the solution. If the violet solution is heated, it becomes green; upon cooling, as long as a month may be required for a return to the original equilibrium condition. Hence, a solution of chrome alum that has stood for some time will contain a considerable variety of ions, including $Cr(H_2O)_6^{+++}$, $Cr(H_2O)_5(OH)^{++}$, $Cr(H_2O)_5(SO_4)^{+}$, H_3O^{+}, K^{+} and SO_4^{--}.

It was pointed out in the previous section that bisulfite forms a coordination complex with chromium. A chrome-alum fixing bath sulfurized rapidly unless the molal ratio of sulfite to chromium exceeded 1:1, while the presence of a sulfite-to-chromium ratio of 2:1 conveyed soluble properties upon the chromium ion at all acid *p*H values. Thus, coordination of bisulfite by the chromium removes the bisulfite ion from solution, and it is no longer free to act as an inhibitor of sulfurization and cannot be detected by the aldehyde procedure for the analysis of fixing baths. Since bisulfite is a negatively charged ion, coordination with the positively charged chromium ion will result in a reduction of the net positive valency of the complex ion. It was previously shown that the presence of excess sulfite in a

fixing bath caused more rapid deterioration of the hardening properties of the bath, but, except for the expected reduction in valency of the chromium, it could not definitely be stated in which forms the chromium would harden satisfactorily or what happened to the ionic form when the bath had lost its hardening properties.

In order to establish the ionic forms of chromium that are responsible for the hardening action, it is necessary to know the number of

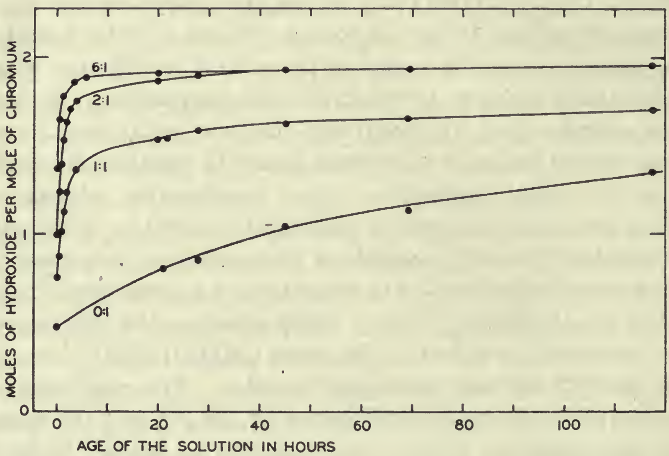

FIG. 10. The influence of sulfite concentration upon the rate of coordination of hydroxide with chromium at pH 4.0. The sulfite concentration is varied from 0:1 to 6:1 molal ratio in solutions of 25 grams per liter of chrome alum that were adjusted to pH 4.0 before the addition of the chromium and kept at pH 4.0 by frequent addition of measured sodium hydroxide. Two hydroxyl groups are associated with each chromium atom when equilibrium is reached at pH 4.0. The rate at which equilibrium is attained is directly proportional to the sulfite concentration.

hydroxyl groups associated with each chromium ion and the net charge on the complex ion. Consequently, various chromium solutions were prepared and their properties studied as the solutions aged. One rather simple way in which the number of hydroxyl groups associated with each chromium atom can be determined, at any time interval, is to measure the amount of standard sodium hydroxide that is required to keep the pH of the solution at a constant value. The results of a series of such determinations are plotted in Fig. 10 as a function of time. A pure solution of chrome alum undergoes hydrolysis rather slowly as indicated by the curve, some 40 hr being neces-

sary for the liberation of one equivalent of acid at a pH of 4.0 and a temperature of 25 C. The series of aging curves at various sulfite-to-chromium-molal ratios reveals the great effect of sulfite concentration upon the rate of hydrolysis of the chromium. Sulfite does not appear to alter the equilibrium number of hydroxyl groups on each chromium at a pH of 4.0, but it very definitely affects the rate at which the equilibrium is reached. Thus, in the solution containing a sulfite-to-chromium-molal ratio of 6:1, a degree of hydrolysis is ob-

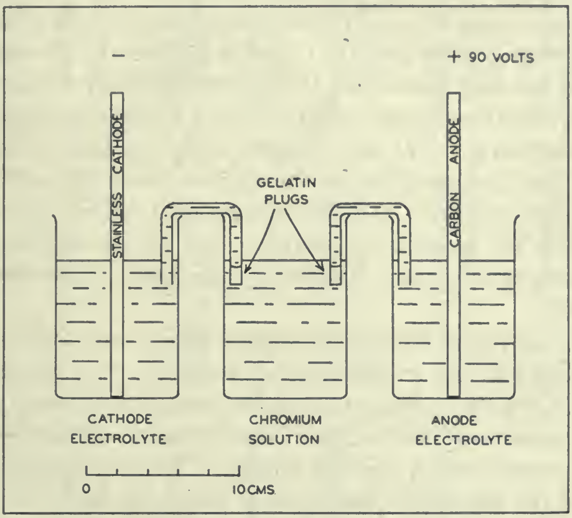

FIG. 11. Apparatus for determining the ionic charge on the chromium complex molecules and the effect of the charge upon gelatin hardening. Chromium ions with a positive charge harden gelatin irreversibly, while chromium with a zero or negative charge produces a mild hardening that is reversed by washing.

tained in a few minutes that requires a week for the plain chrome-alum solution. A similar set of curves, determined at pH 5.0 (not shown), reveals the same relationship, with an equilibrium value involving a greater number of hydroxyl groups.

The information that is obtained from the foregoing experiments suggests the cause for the loss of hardening properties of chrome-alum baths, and shows the influence of sulfite concentration upon the rate of loss but it alone is not enough to indicate the reactions which occur. In order to obtain additional information upon the nature of the hardening process, these same solutions were subjected, at definite time

intervals, to qualitative ion transfer experiments and motion picture film hardening tests.

When a potential difference exists between electrodes that are immersed in a solution, ions are attracted to the electrodes of opposite charge and the migration of the ions within the solution conducts the current. Since the ions of chromium are highly colored, migration of the complex ions can be determined by visual examination of their travel into the salt bridges of the apparatus shown in Fig. 11. It has been demonstrated that a gelatin gel offers practically no resistance to ion migration, unless the ions form chemical compounds with the gelatin. Hence the gelatin plugs in the solution ends of the salt bridges provide free ion migration from the solution without mechanical mixing and, in addition, enable observation of any chemical reaction or physical hardening. The salt bridges contain a solution of sodium sulfate of the same molality as the chrome-alum test solutions and are adjusted to the same *p*H with sulfuric acid. The results of some of these tests are presented in Table 1 and are so important to the interpretation of chromium hardening that they will be discussed in some detail.

A freshly prepared solution of chrome alum contains most of the chromium ions in the trivalent form, $Cr(H_2O)_6^{+++}$, which is violet in color. When the potential is applied across the gelatin plugs, the violet ions enter only the cathode compartment, indicating that the chromium carries only a positive charge. With continued electrolysis, most of the chromium ions quickly travel the length of the plug, staining the gel as they travel and gathering in greatest concentration at the negative end of the plug; none of the chromium leaves the gel. This experiment indicates that the attraction of gelatin for $Cr(H_2O)_6^{+++}$ ions is sufficient to overcome the potential gradient within the solution and that chemical combination must occur. The fact that the violet ions tend to migrate to the negative end of the gel shows that the positive valency of the chromium has not been satisfied by the combination with the gelatin. The gelatin layer that contains the chromium is completely insoluble in boiling water, while the corresponding anode section is unhardened.

The chrome-alum solution aged at *p*H 4.0, which had hydrolyzed to the ion $Cr(H_2O)_5(OH)^{++}$, was tested for ion migration. Chromium entered the cathode compartment only, and in this case the cathode gel, after an hour of electrolysis, had become stained violet in color near the positive end of the gel and green in color at the nega-

TABLE 1

Solution	pH	Ion Migration	Postulated Ionic Form	Hardening Actions
(1) Cr Alum 25 gm per liter Fresh	3	Cathode only	$Cr(H_2O)_6^{+++}$	Hardens film in hardening bath; hardens cathode gel
(2) Cr Alum 25 NaOH 2.0 Fresh	5	Cathode only	$Cr(H_2O)_5(OH)^{++}$	Hardens film in hardening bath; hardens cathode gel
(3) Cr Alum 25 NaOH 2.0 Na_2SO_3 6.0 Fresh	5	Cathode only	$Cr(H_2O)_4(HSO_3)(OH)^+$	Hardens film in hardening bath; hardens cathode gel
(4) Cr Alum 25 NaOH 1.8 Aged 24 hr	4.0	Cathode only	$Cr(H_2O)_5(OH)^{++}$ $Cr(H_2O)_5(SO_4)^+$	Hardens film in hardening bath; hardens cathode gel
(5) Cr Alum 25 NaOH 3.2 Aged 24 hr	5.0	Cathode only	$Cr(H_2O)_4(OH)_2^+$	Hardens film in hardening bath; hardens cathode gel
(6) Cr Alum 25 NaOH 3.7 Na_2SO_3 6.0 Aged 24 hr	4.0	Cathode only	$Cr(H_2O)_4(HSO_3)(OH)^+$ $Cr(H_2O)_3(HSO_3)(OH)_2$	Hardens film in bath; gives additional hardening on drying. Hardens cathode gel
(7) Cr Alum 25 NaOH 3.8 Na_2SO_3 6.0 Aged 24 hr	5.0	Cathode only	$Cr(H_2O)_4(HSO_3)(OH)^+$ $Cr(H_2O)_3(HSO_3)(OH)_2$	Hardens film in bath; gives additional hardening on drying. Hardens cathode gel
(8) Cr Alum 25 NaOH 4.0 Na_2SO_3 18 Aged 48 hr	4.0	None	$Cr(H_2O)_3(HSO_3)(OH)_2$	Does not harden film in bath; hardens film on drying
(9) Cr Alum 25 NaOH 4.6 Na_2SO_3 18 Aged 24 hr	5.0	Anode only	$Cr(H_2O)_3(HSO_3)(OH)_2$ $Cr(H_2O)_2(HSO_3)_2(OH)_2^-$	Does not harden film in bath; hardens film on drying

tive end. The green chromium ions retained a net positive charge within the gel, while the violet ions did not and were deposited as they entered the gel and combined with the gelatin groups. The green form is the ion $Cr(H_2O)_5(OH)^{++}$, while the violet ion is probably $Cr(H_2O)_5(SO_4)^{+}$.

Other chromium solutions were tested in this apparatus, with the results that are shown in the table. It was found that, whenever any positively charged chromium ion entered the cathode gel and stained it, the gel was hardened so that it was insoluble in boiling water. The solutions that contained chromium with a net zero charge gave no ion migration, but the slow diffusion of these ions into both the cathode and anode gels formed stained skins that were hardened to a mild degree. The chromium from these tests readily washed from the gels and the gels swelled in water, melting at relatively low temperatures. The anode gels from the tests involving transfer of chromium ions of negative charge were also hardened to a moderate degree and had the properties of the gels that were hardened with chromium of zero charge. Hence the gelatin plugs that figured in the ion migration experiments showed 2 types of hardening with chromium. The hardening produced by any of the positively charged chromium ions is complete and permanent; chromium cannot be washed from the gels or removed by reversal of the emf, and definite chemical combination must occur between the positive chromium ions and the negatively charged gelatin carboxyl groups, with the formation of coordination-type chromium molecules that are restricted to the gel. This type of hardening is relatively independent of the concentration of chromium within the bath, since the gel will tend to react with chromium until the negatively charged carboxyl groups are satisfied. Combination of the gel with chromium molecules of zero charge and even negatively charged chromium ions does occur, but in this case the combination is weak and is reversed by washing; combination of this type is thus of the nature of an adsorption process. It is probable that the molecular or negatively charged chromium unites with gelatin by the same mechanism that permits combination with positively charged chromium, namely by coordinating with gelatin carboxyl groups, but there is no favorable charge to make the bond tenacious and therefore the reaction is reversed merely by dilution.

Motion picture negative film samples that were developed and hardened in these aged chromium sample solutions proved to be

hardened only by those solutions which contained positively charged chromium ions. Solutions in which the chromium had a charge of zero or negative were entirely without hardening action. Combination of gelatin carboxyl groups and negative chromium would not be expected to take place, except under the unusual conditions that are encountered in the ion migration experiments, where unfavorable charge is overcome by an applied emf. Uncharged chromium, however, is unaffected by the charge on the gel and such ions are free to enter a gel by diffusion.

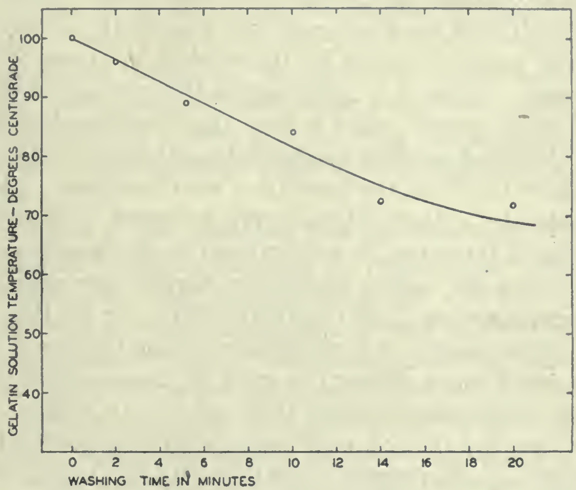

FIG. 12. The effect of washing film after fixation upon the melting point of *dried* negative film that is fixed in a bath of chromium possessing a net zero charge. No hardening is produced until the film is dried and the adsorbed chromium tends to be removed during the washing process.

While film is unhardened by molecular chromium during normal film fixation, the chromium that is left in the film combines actively with the gelatin during the drying process; even in the dry state the combination of molecular chromium with gelatin carboxyl groups continues to take place and the film becomes increasingly insoluble upon standing. Fig. 12 shows the effect of washing time upon the hardening produced after drying for film that was bathed in a chrome-alum bath that contained chromium of zero charge. Oxidation of coordinated bisulfite groups or loss as sulfur dioxide could cause a

return of positive charge that would favor the combination with gelatin that occurs during and following the drying process. Negatively charged chromium ions have no hardening action upon the gelatin of motion picture films, either during processing or following the drying operation.

The chrome-alum solutions that contained bisulfite, and that were shown to reach equilibrium with respect to hydroxide at different rates (Fig. 10), proved to lose their positive charge in a manner that is directly related to the presence of hydroxyl groups. The solutions at *p*H 4.0 that involved 2 hydroxyl groups for each chromium atom were found to contain only chromium of zero charge. The same conditions (*p*H 5.0) that involved more than 2 hydroxyl groups produced chromium of negative charge by the amount in excess of the 2 hydroxyl groups. Hence it is quite certain that chromium coordinates with one bisulfite group (when at least this much bisulfite is present) and that additional bisulfite catalyzes the attainment of the equilibrium condition involving the basicity of the chromium. Thus, at *p*H 4.0, the molecule $Cr(H_2O)_3(HSO_3)(OH)_2$ is formed as an end product, and the rate of formation is proportional to the bisulfite concentration. At higher *p*H values, negatively charged ions are formed that can be diagrammed as $Cr(H_2O)_2(HSO_3)(OH)_3^-$ or $Cr(H_2O)_2(HSO_3)_2(OH)_2^-$. Consequently, it is possible to explain the loss of hardening properties which occur during the aging of chrome-alum fixing solutions. The chrome-alum baths that are low in sulfite (especially those with less than the 1:1 molal ratio) will retain positively charged chromium ions of the form of $Cr(H_2O)_4(OH)_2^+$ or $Cr(H_2O)_4(HSO_3)(OH)^+$ for a considerable length of time and they will, therefore, retain their active hardening properties.

Chromium solutions, both with and without thiosulfate, give identical results in the experiments that are outlined above; it is reasonable to assume that thiosulfate ions do not form coordination type complexes with chromium ions, in spite of the high concentration of this substance in photographic fixing baths. It is evident that the presence of any additional negatively charged ions that will coordinate with chromium (especially the salts of organic carboxylic acids) will tend to eliminate the rather small number of positively charged chromium ions and will hasten the loss of hardening within the solution. It is for this reason that Crabtree and Russell[6] found that the organic carboxylic acids, such as acetic acid, were unsuitable for use with chromium fixing baths.

The evidence strongly indicates that the hardening of gelatin by chromium and by aluminum follows the same mechanism, consisting of the formation of coordination complexes between gelatin carboxyl groups and the metal ion of positive charge. This view is supported by the spectrophotometric measurements of Kuntzel and Riess,[7] who obtained very similar curves for chromium in the presence of gelatin, glycocoll, and acetic acid, and of Kuntzel and Droscher,[8] who gave evidence for the formation of complex salts between chromium and gelatin. Conditions are most favorable for coordination (hardening) when the maximum number of metal ions have a positive charge and when the maximum number of gelatin carboxyl groups have a negative charge. Positive charge for the metal ions is favored by a low *p*H, while negative charge for the gelatin carboxyl groups is favored by high *p*H; consequently the *p*H range that is favorable to the hardening process is rather narrow and the *p*H of maximum hardening is dependent upon the conditions within the solution and the isoelectric point of the gelatin.

Other concepts of the hardening process have been advanced; it has been suggested that hardening is the result of the precipitation of basic chromium salts within the gel and that coordination of chromium occurs with gelatin amino groups or with the polypeptide linkages of the protein molecules. These concepts are not necessary in explaining the hardening action of chromium and, indeed, are not supported by the evidence, since combination of chromium and gelatin occurs actively with any positively charged chromium ion, even the $Cr(H_2O)_6^{+++}$ ion of no basicity, and combination between positively charged gelatin and negatively charged chromium ions does not tend to take place.

Since the maximum positive valency of chromium in a photographic fixing bath is not likely to exceed one, even at a *p*H value of 4, the valency of the chromium-protein complex is satisfied and there is no appreciable tendency to retain silver thiosulfate. Consequently, chrome-alum fixing baths have silver and hypo retention properties at *p*H 4.0 that are comparable to the properties of aluminum baths at *p*H 6.0, where a similar situation exists with respect to ionic charge.

Practical Operation of a Chromium Fixing Bath.—In the previous section it was pointed out that chromium produces 2 types of gelatin hardening, depending upon the charge on the chromium molecule. Chromium molecules of positive charge harden gelatin very well, usually rendering it insoluble in boiling water as it leaves the

hardening bath; moreover, the hardening process is relatively independent of the chromium concentration. The other type of hardening does not occur until the film has been dried and is caused by the retention of uncharged molecules of chromium which combined chemically with the gelatin during and following the drying of the film. This type of hardening contributes nothing to the safety of handling during processing but produces satisfactory projection and handling properties as the film stands after being dried.

The type of hardening that is produced by positively charged chromium ions is the more desirable, since it is during the processing of the film that it is most easily damaged. In order to obtain this type of hardening consistently, it is necessary to maintain careful chemical control over the hardening bath as it is being used. Loss of positive charge on the chromium complex results from the increased *p*H in the solution and the presence of too much bisulfite. The hardening properties can be retained most readily in a chromium bath by keeping the *p*H of the bath at 4.0, or somewhat below, and by maintaining a sulfite-to-chromium-molal ratio that is less than 2:1. While the hardening qualities of such a bath are excellent with sulfite-to-chromium ratios of 1:1 or less, so little free sulfite exists in the solution that it sulfurizes very rapidly. Consequently, satisfactory operational qualities are maintained only if the ratios of sulfite to chromium lie between 1:1 and 2:1.

Control over the *p*H of the fixing bath is necessary in plant operation in order that the action of development will be stopped uniformly; although the actual *p*H value that is selected for control may vary from 3 to 5, it is probably most satisfactory to regulate the *p*H to a value of about 3.8. The lower the *p*H value that is selected for control, the higher may be the sulfite-to-chromium ratio, without losing the hardening properties of the bath. Russell and Crabtree[9] have shown that fixing baths should not be used at *p*H values much less than 4.0, if the silver image is not to be "reduced" by the solvent action of the bath. At *p*H values as high as 5, so little sulfite may be used (only a 1:1 ratio) that control is very difficult. At *p*H 3.8 the silver density reduction properties of the bath are low, the sulfurization properties are not critical, and the hardening properties are satisfactorily retained at sulfite-to-chromium ratios up to 2:1. Fig. 13 illustrates the manner in which a chromium fixing bath of 2:1 sulfite-to-chromium-molal ratio maintains its hardening properties with age at *p*H 4.0.

The preparation of a chromium fixing bath should follow the procedure that is designed to delay loss of positive charge on the chromium as long as possible. Under no circumstances should any of the organic acids, such as acetic, citric, or formic, be used in its preparation or control. The desired quantity of sodium thiosulfate should be dissolved first in water that is high enough in temperature to pro-

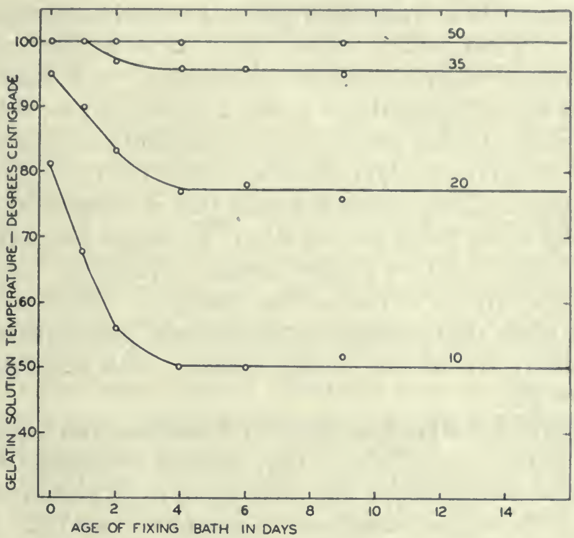

FIG. 13. The melting point values of negative film developed, rinsed, and fixed in chrome-alum fixing baths containing 350 grams per liter of hypo and a 2:1 molal ratio of sulfite to chromium for various chrome-alum concentrations from 10 grams per liter. Baths are controlled to pH 4.0 by frequent addition of sodium hydroxide. If the molal ratio of sulfite to chromium does not exceed 2:1, the hardening properties tend to be retained at pH 4.

duce the hypo solution at room temperature or below. The anhydrous sodium sulfite should next be added to the hypo solution in an amount that is related to the chrome alum that is to be added later. Enough sulfuric acid should be added to bring the pH of the sulfite and hypo bath down to about 6.0; in this form the bath has excellent keeping qualities and may be stored indefinitely. Just before use, the dry chrome alum should be added to the solution, with good agitation, until the chromium salt has dissolved. If the agitation is not adequate, complete solution is not possible; hence, under certain

conditions, it may be preferable to use a solution of chrome alum which has been freshly prepared with the minimum amount of cool water. The *p*H of the solution after the addition of the alum will be close to 4 and it will become lower upon standing. This bath will not lose its hardening properties completely upon standing, but for satisfactory operation it is necessary that the *p*H be controlled by addition of sulfuric acid or sodium hydroxide.

Replenishment of a chromium fixing bath should be based on proper maintenance of *p*H, sulfite concentration, hypo concentration, and concentration of positively charged chromium. It is most satisfactory to add the sulfite and hypo in the dry form and to replenish the chromium with a freshly prepared saturated solution of chrome alum. As little as 0.5 gram per liter of chrome alum per day is required to maintain the hardening action of a bath that is in constant use.

Chromium fixing baths are not nearly so simple to operate as are aluminum baths, but they possess certain advantages. In addition to a somewhat greater degree of hardening, the use of a chromium fixing bath, under the conditions outlined above, permits easy removal of silver and hypo from the finished product, with resulting permanence of the film.

The Retention of Hypo and Silver by Aluminum and Chromium.—Crabtree, Eaton, and Muehler[3] have made a comprehensive study of the factors that influence the retention of hypo and silver by film that is fixed in various solutions. Their researches have indicated the difficulty that is experienced in washing hypo and silver from film that is not processed under favorable conditions. An aluminum fixing bath was found to cause retention of much greater quantities of the thiosulfate complex than was caused by a chromium bath, and it was found that the aluminum bath had much better properties when operated at *p*H values above the isoelectric point of gelatin.

Limited experiments in this laboratory have confirmed the observations of the above authors and, in addition, have shown that chromium may retain hypo and silver and that aluminum may not retain these substances, depending upon the complexing anions that are present. Since aluminum and chromium normally differ decidedly in their retention properties, it is not likely that the isoelectric point of gelatin bears any more than incidental relationship to the retention problem. It was found that the aluminum-citric acid formula discussed earlier had retention properties at *p*H 4.2 that were the equal of the properties of the aluminum-acetic acid-boric acid

bath at pH 5.0, even though practically equal hardening was produced. Also, the properties of the chromium fixing baths, with a 3:1 molal ratio of sulfite to chromium, were better at low pH values than the bath with the 1:1 ratio.

The above authors found that hypo retention generally parallels silver retention; this suggests that the mordanting action involves the coordination of a complex silver thiosulfate ion, the simplest of which is the ion, $AgS_2O_3^-$. Since this ion is negatively charged, it will tend to coordinate with positively charged complex metal ions but it will not readily coordinate with neutral molecules or negatively charged ions. Aluminum retains the thiosulfate complex when its coordination with gelatin carboxyl groups still leaves the group with a positive charge. Reduction of the net positive charge by complexing with citrate ions or by increasing the pH precludes the possibility of coordinated $AgS_2O_3^-$ groups. If the thiosulfate complex is coordinated with aluminum in the fixing bath and such groups become fixed to protein carboxyl groups, they can be removed in the washing process by metathesis with hydroxyl groups, which explains the helpful action resulting from the addition of alkali to the wash water.

Divalent positively charged chromium ions are rarely present in chrome-alum fixing baths because coordination of one bisulfite group and one hydroxyl group occurs almost at once. Divalent chromium exists in fixing baths of low sulfite concentration and low pH; such solutions cause retention of silver and hypo as is the case of aluminum.

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THE APPLICATION OF PURE MATHEMATICS TO THE SOLUTION OF GENEVA RATIOS *

RON W. JONES**

Summary.—*A method is described and formulas given to determine mathematically the relative angular displacement and film velocity ratios in the regular Geneva movement as used in 35-mm motion picture projectors.*

The subject of Geneva movement analysis has been ably dealt with in the literature. The author, however, feels the urge to contribute his small share and to this end sets out herein a system of direct ratio solution by means of pure trigonometry.

The method described was evolved during an analysis of relative film velocities with a view to investigating the possibilities of optical compensation for intermittent film motion. Experimental work in this direction has indicated the necessity of near sine wave motion with the possible expansion of the pull-down period to 180 deg. A knowledge of Geneva movement curve diagrams was essential and it was deemed desirable, in view of other aspects of the work, to resort, if possible, to pure mathematics.

It is not the purpose of this paper to set forth other than the methods and formulas employed to obtain the relative angular displacement and velocity ratio values for the orthodox Geneva movement as used in 35-mm motion picture projection equipment.

Fig. 1 displays a four-to-one movement at rest in a position wherein the cam pin has entered the starwheel slot to a depth equal to half its own diameter. This may be termed "start of pull-down period" and all ratio characteristics may be observed during the 45 deg of cam rotation immediately following this point. Obviously this supplies all necessary data for plotting the half curves. The full 90-deg curves are obtained by continuation to the right of the 45-deg abscissa since the second half represents a reversal of the first.

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* Submitted Jan. 11, 1946.

** Western Electric Company (Aust.) Pty., Ltd., Brisbane, Australia.

Relative dimensional ratios with reference to Fig. 1 are as follows:

$$\eta = \gamma = 45°$$
$$\mu = 90°$$
$$a = c = b \cos \gamma = b \sin \gamma$$

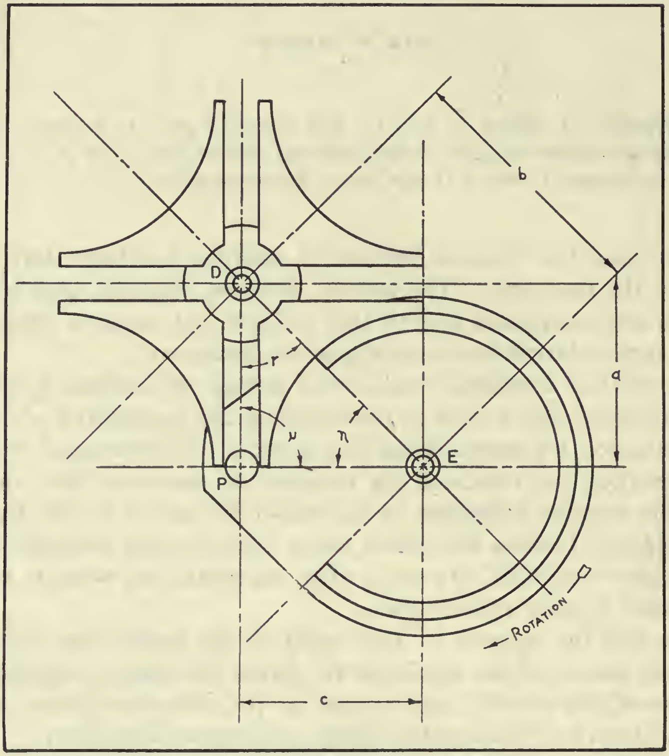

FIG. 1.

The first curve to be plotted is that for relative angular displacement for cam and starwheel. Fig. 2 represents, schematically, a 5-deg rotation of the cam from original zero position and solution for γ may be obtained from

$$\tan \frac{\mu - \gamma}{2} = \frac{b - c}{b + c} \tan \frac{\mu + \gamma}{2}$$

For logarithmic computation

$$L \tan \frac{\mu - \gamma}{2} = \log (b - c) - \log (b + c) + L \tan \left(90° - \frac{\eta}{2}\right)$$

At zero position taking c as unity then

$$b = \frac{1}{\cos \eta} = 1.414$$

so that, solving for a 5-deg cam displacement, we have

$$L \tan \frac{\mu - \gamma}{2} = \log 0.414 - \log 2.414 + L \tan \left(90^\circ - \frac{40^\circ}{2}\right)$$

$$\text{“} \quad = \bar{1}.2343 + 10.4389 = 9.6732$$

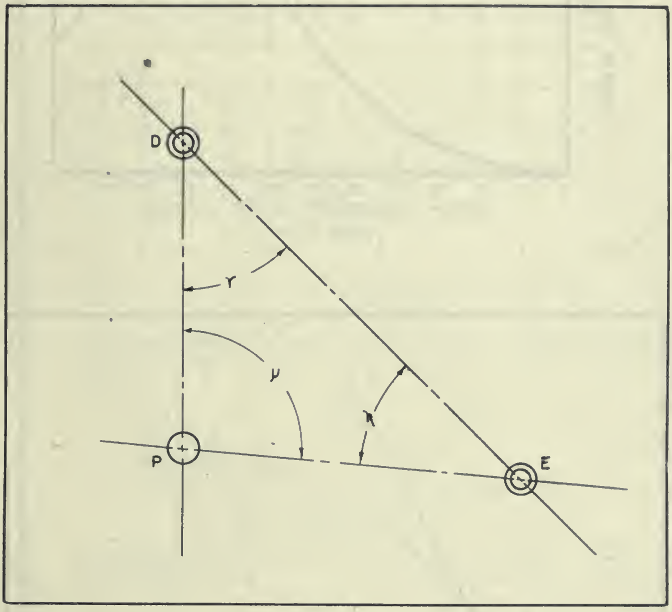

FIG. 2.

whence

$$\frac{\mu - \gamma}{2} = 25^\circ 14' \text{ or } \mu - \gamma = 50^\circ 28'$$

Now

$$\frac{\mu + \gamma}{2} = 90^\circ - \frac{\eta}{2} = 90^\circ - 20^\circ = 70^\circ$$

so that $\mu + \gamma = 140^\circ$.

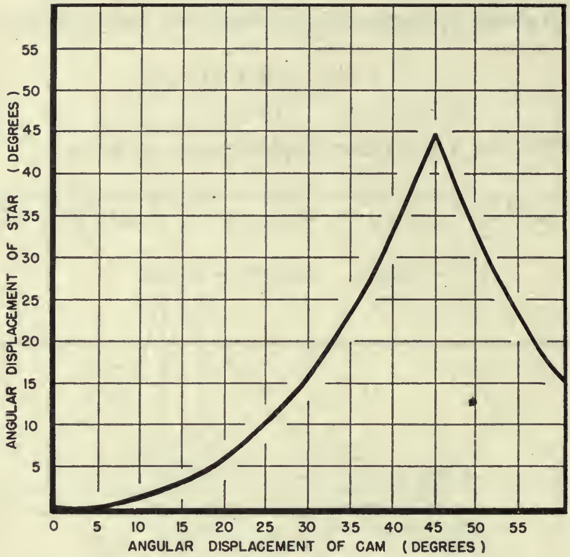
ANGULAR DISPLACEMENT OF STAR (DEGREES)
5 10 15 20 25 30 35 40 45 50 55
0 5 10 15 20 25 30 35 40 45 50 55
ANGULAR DISPLACEMENT OF CAM (DEGREES)

FIG. 3.

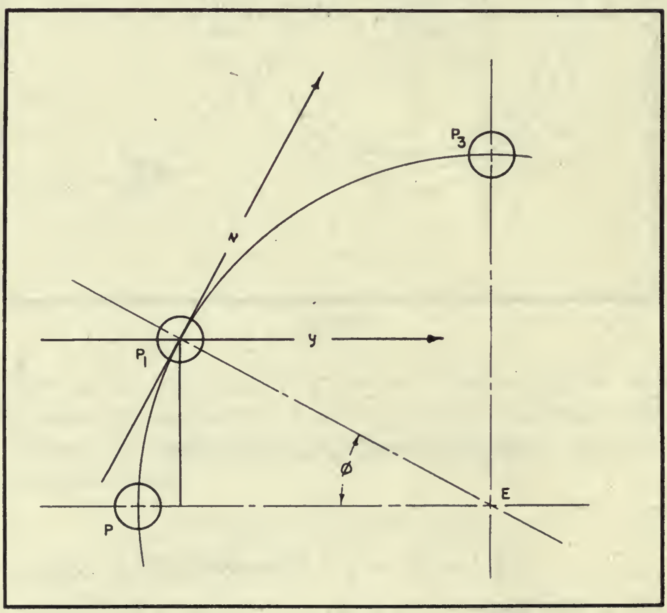
P_3
P_1
y
ϕ
E
P

FIG. 4.

By subtraction

$$\begin{array}{r}\mu + \gamma = 140°00' \\ \mu - \gamma = \ \ 50°28' \\ \hline 2\gamma = \ \ 89°32' \\ \hline\hline \end{array}$$

$$\therefore \text{Starwheel displacement} = 45° - 44°46' = 14'$$

Repeated solution for successive 5-deg steps of cam rotation gives the corresponding increments of starwheel displacement and from this we obtain the curve as in Fig. 3.

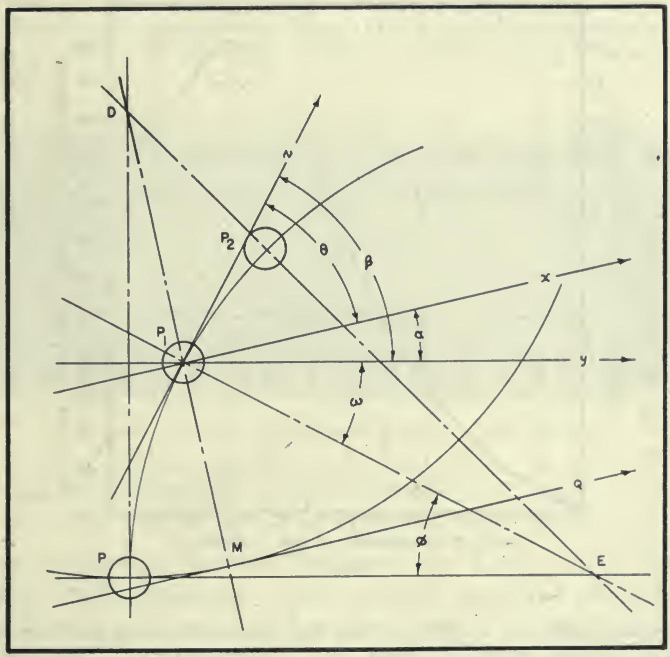

FIG. 5.

The value $\log (b - c) - \log (b + c)$ is a constant, remaining $\bar{1}.2343$ for all applications.

Consideration may now be given to the linear velocity of the cam pin. Fig. 4 shows the cam only and P_1 represents any position of the pin between P and P_3. If we take $PE = R$, linear velocity $= V$, and $rpm = S$, then obviously

$$V_s = S2\pi R$$

and

$$V_y = \sin \phi \, S 2 \pi R$$

From this we may obtain the linear velocity of the pin in any positive direction and thus the value V_x in Fig. 5 in which P_1 represents the pin at its intersection with the starwheel slot DM, and x is normal to DM.

Now since y is parallel to PE, $\sin \phi = \sin \omega$, and since $\omega + \beta = 90°$, β is complimentary to ω, so that $\cos \beta = \sin \omega = \sin \phi$.

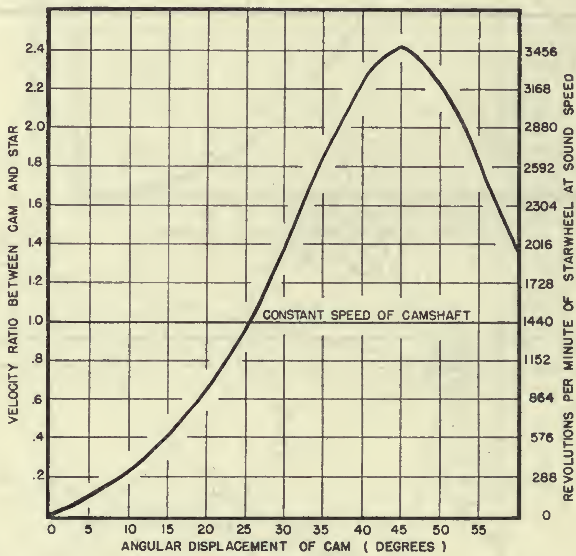

FIG. 6.

At zero position $\theta = 90°$ and as the cam and starwheel revolve in engagement θ diminishes until finally, at 45 deg cam position, $\theta = 0$.

It is evident then that at any point we may obtain V_x from $V_x = \cos \theta \, S 2 \pi R$.

The value V_q (*i.e.*, linear velocity of starwheel tip) may thus be found from

$$V_q = \cos \theta \, S 2 \pi R \frac{DM}{DP_1}$$

Our Fig. 3 curve gives values of α for corresponding values of ϕ so that θ may be found for any position from $\theta = 90° - (\phi + \alpha)$.

From the foregoing equations we may, by progressive solutions, plot the curve (Fig. 6) showing the velocity ratio between cam and starwheel and the instant starwheel velocity, at any angular position, in revolutions per given time period.

The following facts which are revealed are of interest:

(*1*) From zero to 7-deg cam rotation there is very little movement of the starwheel, which contributes in no small measure to the ability of a 90-deg shutter blade adequately to obscure the normal pull-down period, providing the shutter is working at a reasonable beam diameter.

(*2*) From zero to 25.5 deg the starwheel is at a lower velocity than the cam. Beyond the 25.5 deg the starwheel velocity is in excess of the cam velocity.

(*3*) From zero to approximately 30 deg the rate of acceleration of the starwheel increases. Between 30 and 35 deg it remains almost constant. Beyond 35 deg it decreases.

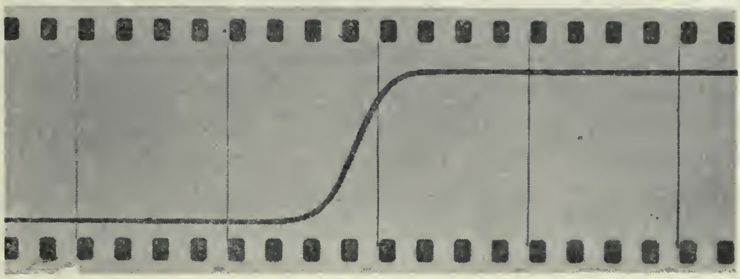

FIG. 7.

(*4*) Top speed of starwheel: 3470 rpm (58 rps.)
Top speed of film: 867.5 ft per min (14.5 ft per sec)

As an interesting practical check on Fig. 3, this curve was also recorded photographically. The method employed involves the exposure of a moving strip of motion picture positive film to the projected image of a small hole drilled in a steel film running through the projector.

The unexposed film is enclosed in a lightproof container mounted directly in front of the projector mechanism. A 4-frame standard sprocket, mounted internally and driven continuously at one-to-one directly from the projector camshaft, is arranged to drive the film horizontally across a narrow scanning aperture in the front of the container and in line with the optical axis of the projector.

The standard perforated steel film is threaded through the projector gate and driven by the intermittent sprocket in the normal

manner, the projector shutter being removed so that the complete cycle is unobscured. An extension barrel fitted to the objective lens permits of the lens being worked far enough forward to focus a one-to-one image at the surface of the unexposed film. At single-frame intervals the steel film is drilled $^1/_{64}$ in. in the center of the normal picture area.

The developed film carries a photographic trace of the spot image and this is, in effect, a recorded diagram of the relative angular positions of cam and starwheel throughout the complete pull-down period. The remaining 270 deg, during which the starwheel is at rest, is recorded as a straight line since the spot image is stationary.

Fig. 7 is a print from the original record.

Projection of the negative onto a sheet of co-ordinate paper enables us to obtain values for the curve, which in fact, are almost identical with our calculated values.

The author wishes to express his appreciation of the assistance rendered him by D. Urquhart and W. Kersley in the construction and operation of the apparatus for obtaining the above-mentioned photographic diagram.

A NATIONAL FILM LIBRARY—THE PROBLEM OF SELECTION*

JOHN G. BRADLEY**

Summary.—*Some pictorial evidence of all motion pictures produced should be preserved. Bulkiness of material, however, and expense of handling makes preservation of all motion pictures in their entirety impracticable. A solution may be found in the use of film strip which would preserve one frame of each important scene.*

The Library of Congress proposes to preserve a considerable part of the motion pictures produced. Considerations in selection policy include possible uses to be made of such a collection, the avoidance of repetitious matter, and the public acclaim given such material in the form of both critical opinion and box office returns.

The collection will be world-wide in scope and will include both 35-mm and 16-mm film. The motion picture industry is invited to cooperate in creating a national film library on the theory that such a library will be mutually advantageous to all concerned —government, education, research personnel, procedures, and others.

If money, personnel, and related facilities were available the simplest method of assembling a motion picture library collection would be to include all available material for permanent preservation. This method has the virtue of requiring little if any exercise of judgment but carries its own penalties as will be noted later in this discussion.

A second method would be to include all available material as before but control its volume and subject matter content through periodic diminutions.

A third method, the one that has been used by the Library during the last 2 years, is based on selections through preaudits. Both the second and third methods require the exercise of judgment, one in advance of the selections and the other following a period of reflection.

A fourth method, one that is presently recommended, is also based on selection as opposed to total collection and contains some

* Presented Oct. 15, 1945, at the Technical Conference in New York.

** Director of the Motion Picture Project, The Library of Congress, Washington, D. C.

elements of preauditing. It differs principally from the method previously used in that it admits a greater segment of the public in the determination of the items selected.

If precedent has any value in this connection it should be pointed out that neither The Library of Congress nor the National Archives has found it expedient to preserve everything available. For example, if the National Archives undertook such a course it would find itself encumbered with a million and one items such as carbon copies of the originals, work sheets, receipts and invoices, punch cards, cancelled money orders and vouchers, and miscellaneous forms that had served their legal and administrative functions and that contained little historical value or permanent interest. In other instances it would find such information to be highly repetitious with only occasional variants having significance. In still other instances it would find that much of the essential information found in such material had been siphoned off into less bulky form such as statistical tables. In any case, the reality of the situation in terms of handling and storage costs as they relate to Government records became acute and led to the enactment of special disposal legislation in an effort to resolve the problem.

A similar reality exists for The Library of Congress in the case of motion pictures, a reality that is intensified by the fact that the volume of such material has already reached major proportions and that this type of material is relatively more bulky and expensive to handle than paper material. Whereas a manuscript or a printed book covering a particular subject might occupy only a fraction of a cubic foot of space and involve a nominal charge to reproduce, a motion picture film on the same subject might require nearly 2 cu ft (six 35 mm reels to the cubic foot) and cost $200 or more to reproduce. The cost of screening and consultation is likewise more expensive, requiring a projection or workroom with special equipment and the services of one or more technicians.

Continuing the comparison with paper records it may be said that motion pictures also have much repetitious matter. For example, *The Three Stooges*, a series produced by Columbia Pictures, follows the same general pattern throughout the years, the variants consisting chiefly of minor changes in plot, setting, and clothing. The same can be said of the Laurel and Hardy pictures, most of the Westerns, and dozens of others. As in the case of paper records, the siphoning-off process is applicable to motion pictures in the execution of film

strips which will be discussed later. It appears, therefore, that both the volume and nature of the film under consideration as well as the precedents established in archival and library practices would justify only a partial inclusion of the total material available.

Indeed no alternative plan seems feasible at the moment. Responsible judgment will be required, however, in formulating a selection technique that will adequately serve the ends sought, that will be sufficiently basic to serve as a major premise and at the same time sufficiently flexible to accommodate itself to changing circumstances. Upon what factors will judgment be exercised and who will participate in exercising it? What are the service implications of such a collection? What kinds of films should be considered and from what sources should they be acquired? How much film should be included? These are a few of the considerations that should be taken into account in developing a selection formula for a film library.

Heretofore judgment has been exercised, in making selections for The Library of Congress, by a small group of analysts on the basis of diagnosis (preaudits) in terms of certain rather fugitive preconceptions such as *good or bad*, *true or false*, *appropriate*, and the like. On the whole the canons of selection, previously used by The Library of Congress, cover the general direction in which the movement should go. But no small group of analysts, regardless of its qualifications, could make selections in terms of diagnosis that would satisfy another group similarly qualified; the factors of judgment are too tenuous. Nor could such a group satisfy the public as a whole; the elements of controversy are too pronounced. This brings us, therefore, to a consideration of public participation—at least, participation by those segments of the public most concerned. While an individual member of the public might make his own selections in terms of the *good or bad* concept, his judgment would be counterbalanced by the judgment of other individuals; likewise the judgments of special groups would counterbalance each other. The result would be a general acceptance of what *is* rather than a search for what *should be*, which is the Library's present attitude toward the printed page. If such participation is allowed and proves successful the collection would represent a broad horizontal foundation upon which each person in his own time could erect his own vertical structure in terms of his own individual interests.

More specifically what segments of the public should be asked to participate? The answer to this question can be suggested by a con-

sideration of the consumer pattern as, Who saw the pictures? How many saw them? Where were they seen? *etc.* Again, what do the critics, steeped in the tradition of the movies, think of them? How do the producers themselves evaluate their own product? There are also many reviewing groups throughout the country that reflect critical opinion in terms of special interests such as education, religion, and the like; what evaluation do they place on the different pictures? These are all valid, elemental, and determinable factors. They are widespread in their significance and democratic in character. The composite judgment of such segments, being self-imposed, should prove generally acceptable to all concerned. The deficiencies, if any, found in a collection resulting from such participation could be corrected by The Library of Congress.

Perhaps one of the most important considerations in terms of this discussion is the service implications of such a collection. In other words, who will use it and how will it be used? The statement has been made in this connection that such a collection should serve the needs of future historians. No objection is offered to such a suggestion. Certainly no medium records our comings and goings quite so graphically as does the motion picture nor offers the historian quite so rich a warehouse of source material with which to evaluate the past. Even the producer may turn historian on occasion with profit to himself both in terms of box-office returns and pride in his craft. But no priority should be given to the historian at the expense of many others having an equal interest in such material. These *others* would include students of the manifold arts as reflected in motion pictures such as music, the dance, make-up, costuming, speech, and drama in general; scientists and technicians having an interest in optics, electronics, and photochemistry; sociologists and psychiatrists interested in human behavior; business men contemplating investments; public leaders and public officials who may want to mobilize our national resources through the use of this medium in some great crisis; producers looking for research material as well as actual footage on nonrestricted films; and taxpayers in general who may be motivated solely by a curiosity in life as mirrored on the screen.

Sources may be divided into several overlapping categories such as domestic and foreign, professional and amateur, government and private, *etc.* Government sources, for example, will yield both original negatives and service prints and the obligation for selecting and

preserving the originals rests with others. Duplicate copies of such films originating with the government, however, along with all non-government films remain eligible for acquisition by The Library of Congress. Perhaps all kinds of films and all available sources should be considered without prejudice. The philosophy of the untouchables would not seem to apply here and no film or source in itself should be regarded as taboo whether the film be an entertainment or an educational film; whether it be a training, propaganda, medical, musical, gangster, or slapstick film; whether, in a broader sense, it be a factual or fictional film; or whether the source be domestic or foreign.

The volume of the collection should be liberal, sufficient to give an accurate index of production and consumption and adequate to serve research needs on a wide front; diminutions can be made later if necessary. The chief limitations with respect to volume would seem to be (*1*) that the collection itself should not become repetitious and (*2*) that it should not seriously duplicate evidence found elsewhere as in the printed page. Thus a film library might not, for example, want all of the *Three Stooges* nor all available newsreels covering a particular event. Such a situation would represent repetitious subject matter. Neither would it want a full motion picture coverage on an extended conference at which no significant action takes place and which could be more economically recorded by other means. In this case the motion picture of the conference would represent needless duplication or expensive substitution. In general the volume of the collection will be determined by quotas on the basis of available funds and the funds will be determined largely on the basis of service rendered. Factual film depicting people, things, and events should be selected on a liberal basis and other films should be selected on a representative basis. It should not be forgotten, however, that in the so-called entertainment film are found many of the basic arts and sciences and that a fictional motion picture itself and in its own right is a *thing*, while those participating in it are certainly *people*.

The burden of this discussion so far has been a consideration of selection versus total collection. There is one aspect of total collection, however, that merits comment; I refer to the possible use of the film strip. This device, in brief, represents a pictorial summary of the complete release which may be consulted through the use of a microfilm reading machine. In other words, it is a strip of film containing a series of still pictures selected from the original release copy in the same sequence as found in the original. In this connec-

tion it should be remembered that each frame in a scene represents a progressive repetition of the subject matter depicted. Thus in one frame a man's hand may appear on a level with his eyes while in succeeding frames it may progress downward until it appears on a level with his waist. The loss sustained in discarding all the frames in a scene except the one or two retained in the film strip would represent primarily only a loss of motion. For most of the potential users of such a collection, especially those interested in documentary studies, such a loss would not comprise a serious handicap. A more serious loss would be that of the sound track; but even this might partially be overcome be rerecording through some microphonographic process and, as far as speech is concerned, through the preservation of the dialogue in script form. In any case the film strip technique would need be applied at first and in terms of this discussion only to those subjects not otherwise selected for preservation. Its possibilities should be explored further.

Another aspect of total collection is found in the literature related to film: production schedules, published reviews, scenarios, cutting continuities, dialogues, and the like. From such material and from kindred sources a union catalogue could be evolved that should prove beneficial to producers and scholars alike. Already The Library of Congress has a priceless collection of material covering all copyrighted film from the beginning of the motion picture industry. The organization of such material on a service basis awaits only the availability of additional funds and personnel.

In applying the proposed formula the following outline of general sources is submitted together with a suggested quota and pertinent comments for each source group listed.

Group 1—American Newsreels.—Acquire the complete edited output of one of the major American newsreel companies for one year and examine the output of the other newsreel companies for possible supplemental material. Alternate this plan from year to year among the companies concerned. The selection of the supplementary material can be made for the most part through an examination of data sheets. Acquisitions to be made currently. Estimated annual yield, approximately 200,000 ft.*

Group 2—American Citations.—Acquire each edited title listed

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* Subject to revision in terms of greater post-war divergence of subject matter among newsreel companies.

one or more times in the following categories: (*a*) Academy citations, (*b*) Film Daily citations including the "ten best" as well as those listed in the so-called honor roll, (*c*) citations by leading newspapers, (*d*) citations by miscellaneous reviewing organizations representing special interests, and (*e*) the so-called box office champions. No screening required; acquisitions to be made at end of the year. Estimated annual yield, 100 titles, or 500,000 ft.

Group 3—Producer Selections.—This group would include citations by the producers of their own pictures not covered in Groups *1* and *2*. In other words, a producer, having invested his best thought, his time, his money, and other resources in the production of a picture, has a right to be heard in the matter of selection and preservation by a public institution. Each producer should be free to set up his own standards of selection; in brief, his selections would represent the pictures he wants the government to preserve. The maximum quota from each producer should be set at approximately 50,000 ft. Acquisitions to be made at the end of the year. Estimated annual net* yield, 100 titles, or 500,000 ft.

Group 4—American Miscellaneous.—Acquire, on a selection and quota basis, other edited subjects from American sources that are not covered in Groups *1*, *2*, and *3* and that will represent a well-balanced cross section of the industry's output. These subjects should include many films that the critics have not acclaimed and the producers have not selected or that may have been box-office failures but that, nevertheless, are a part of the movie production and consumption pattern. Most of these selections could be made on the basis of reviews and data sheets; screenings could be arranged for doubtful cases. Acquisitions to be made at the end of the year. Estimated annual yield, 100 titles, or 500,000 ft.

Group 5—American Government.—This group should include nonrecord film and library copies of record film produced or sponsored by the government. Details covering plans of operation should be worked out jointly with the National Archives. Estimated annual yield, 500,000 ft.

Group 6—American Nontheatrical.—This group should consist principally of factual expository film used for teaching, training, and documenting purposes. It is sometimes referred to as the 16-mm field although many of the negatives are and presently should

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* Total selected less duplications found in Group *2*.

be on the 35-mm size. A substantial part of such film is available through copyright channels but the scope should be materially expanded. No screening implied. Acquisitions to be made currently. Estimated annual yield, 200 titles, or 150,000 ft.

Group 7—Foreign Miscellaneous.—This group should include a well-balanced cross section of foreign productions, world wide in scope, that would consist of newsreels, shorts, features, and expositories. Selections for the most part could be made on the basis of critical opinion. Acquisitions to be made currently. Estimated annual yield, 100 titles, or 500,000 ft.

Group 8—Unedited Footage.—This group may be divided into 2 subgroups: (*a*) film that has been exposed in connection with production work but not used in the final release and that has been set aside as "library shots," and (*b*) related sequences taken from edited or released pictures and compiled into series on such topics as geography, transportation, industry, agriculture, music, speech, sports, and the like. The possibilities of this second subgroup have been discussed with key men in government, industry, and education with favorable reaction but remain to be explored further. Acquisitions to be made currently. Estimated annual yield, 150,000 ft.

The total annual yield under the foregoing plan would be approximately 3,000,000 subject ft, or 900 titles. If both a preservation copy and a service copy could be included for each item acquired, the storage load would be 6,000,000 ft (6000 reels), or approximately 1000 cu ft. *Note:* It should be observed that groups *1*, *2*, *3*, and *4* represent the domestic 35-mm or theatrical field on released material. These 4 groups would yield less than 2,000,000 subject ft a year in newsreels, shorts, and features. The amount of such film thus proposed for selection and preservation represents a little less than 25 per cent of the total output of these 4 source groups, a quota that appears to be entirely reasonable.

In conclusion I wish to say that the plan outlined herein has been discussed widely with government people handling film. It is proposed to discuss it also with leaders in the motion picture industry in an effort to perfect it on a practical basis. It is believed that through such discussions and through other exchanges of opinions and benefits, acquiescence to a plan will be turned into active support of a movement. The benefits which the American people and the government will derive from such a collection through the years to

come are valid and obvious. The use of motion pictures during the recent international struggle has demonstrated the power of this relatively new medium.

The benefits which the producers will enjoy are equally valid, and equally obvious when all the possibilities are considered. For example, the vast resources of the Copyright Office of The Library of Congress in terms of its literature related to motion pictures remain practically unexplored. It is proposed to organize this material and make it easily accessible to everyone interested. The usefulness of a union catalogue on extant film, whether the film itself is in The Library or not, suggests a service possibility that has considerable merit. The screening facilities contemplated in connection with the collection should attract a large patronage. Footage enjoying a public domain status should prove particularly attractive to producers if their relationship with the National Archives and The Library of Congress over the last 2 or 3 years can be taken as a guide.

Finally, there is the consideration of pride of craft. For example, The Library of Congress is proposing to give the screen a comparable recognition to that heretofore given the printed word. Such recognition has been sought by leaders in the motion picture industry for years and Will Hays, Terry Ramsaye, Sol Bloom, and others have been pioneers in the movement. It is also understood that members of the Academy of Motion Picture Arts and Sciences have given serious consideration to such a movement. It is not inconceivable that the proposed national film library should, with the cooperation of all concerned, some day become equal in size and usefulness to the largest general library now in existence. No objection can be lodged against such a possibility if such a library earns its way in terms of service.

DISCUSSION

QUESTION: What is the scientific significance of the proposed collection?

MR. BRADLEY: We expect to build up a great film library containing important scientific data. I would say also that we do not intend to build up any collection competitively; we are going to serve as a central facility and as such we hope to implement what other film libraries are doing in Chicago, Los Angeles, New York, and elsewhere. As a central film library becomes strong it follows that other libraries will be correspondingly strong. In other words, we might regard ourselves as wholesalers and the other libraries of the country as the jobbers.

There are 2 things we do not propose to do: we do not intend to get into film production, nor do we plan to distribute film on a retail basis. We hope, however, to accept some of the burdens of film distribution on a jobber basis corresponding

closely to our interlibrary loan policy in respect to books. In other words, both in the matter of film production and film distribution, we do not intend to invade either the creative or administrative functions of others. After the agency of origin has completed its primary or administrative distribution and after it has turned its film over to The Library of Congress then we will exploit additional values that may be found in the film through supplemental distribution, but on a jobber basis. For the reason that we are not a lending library to individuals in respect to books, neither can we lend films to individuals except, of course, in rare cases.

QUESTION: How will pictures be selected for the Library?

MR. BRADLEY: This is covered in some detail in the text. However, I wish to say that the film will be selected on a referendum basis. For example, if the Academy of Motion Picture Arts and Sciences or the various newspapers of the country or any other interested segments of the public select film as representing the 10 best, the 50 best, or box-office champions, then The Library of Congress will accept such film on the basis of public acclaim. In general, we will select photoplays on a representative basis and factual films on a rather complete basis.

QUESTION: How does this program relate to the film program of the National Archives?

MR. BRADLEY: The National Archives is primarily interested in the records of the government, while The Library of Congress is interested in library material. That is, the National Archives would have a legal interest in the negative and, perhaps, the master positive of a given film subject, while The Library of Congress would be interested in extra copies of the same film. There is no conflict between the 2 programs.

QUESTION: How do you determine the date of selection?

MR. BRADLEY: The selection, for the most part, will be made at the end of the year, but on newsreels and other factual films as well as factual expository films, many of the selections will be made currently.

THE WALLER FLEXIBLE GUNNERY TRAINER*

FRED WALLER **

***Summary.**—A description is given of the equipment devised to train gunners to hit fast-moving targets. The more important and novel features are discussed. The trainer not only reproduces for the observer any desired environment and target, but also correctly simulates conditions of fire in a way that otherwise could only be found in actual combat.*

A humorous slant or gag often conveys an idea better than a serious description. James Reddig, one of the Eastman engineers, was asked by another friend of mine how the gunnery trainer had changed from the experimental model he had seen and what it looked like. Jim replied, "Oh, that's easy. You take the end off the Triborough Bridge, put four men on it with their feet dangling in the air, a console like a church organ, and behind that photocells, amplifiers, levers, scanners, and a lot of other things that I cannot understand. Then, take the Perisphere from the World's Fair, cut it into 4 pieces, push the end of the Triborough Bridge into one of the pieces and you have a Waller Gunnery Trainer. It's just as simple as that."

As this description and Fig. 1 give you an idea of the size and complexity of the machine, it is obvious that a complete analysis and description of the apparatus cannot be given in one paper, so the following covers the more important and novel features.

The purpose of developing this machine was to train gunners, under realistic conditions, to estimate quickly and accurately the range of a target, to track it, and to estimate the correct point of aim when using noncomputing sights. To accomplish this purpose, the Waller flexible gunnery trainer uses a special spherical screen process. This process was conceived by Ralph Walker, a well-known architect, and myself in 1938, and several years were spent in developing the apparatus and overcoming the problems involved.

In June, 1940, H. Martyn Baker, an old friend of mine who is a

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* Presented Oct. 15, 1945, at the Technical Conference in New York.

** Vitarama Corporation, Huntington Station, N. Y.

graduate of the Naval Academy at Annapolis, recognized the possibilities offered by the spherical screen process in the training of gunners to hit fast-moving targets. That was the real start of work on the gunnery trainer.

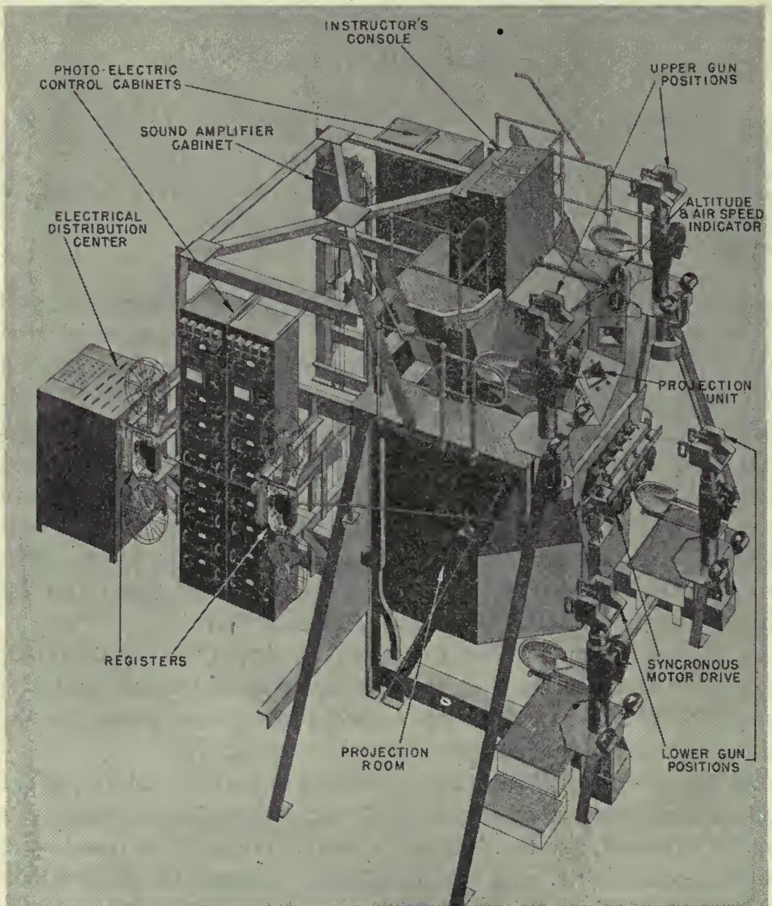

FIG. 1. Bird's-eye view of Waller Flexible Gunnery Trainer—Mark *2*, showing unified assembly of elements.

The fundamental theory of the spherical screen process is that for the average individual the perception of distance, beyond about 20 ft, is not so much the result of binocular stereopsis as it is of peripheral

vision, relative movement, size of object, and atmospheric perspective. By peripheral vision I mean what the eye sees outside of its central area of sharp focus. This screen process simulates what the eye normally perceives by filling a screen, shown in Fig. 2, which is a portion of the inside of a sphere, with a motion picture. The angular dimensions of the screen, 150 deg in the horizontal and 75 deg in the

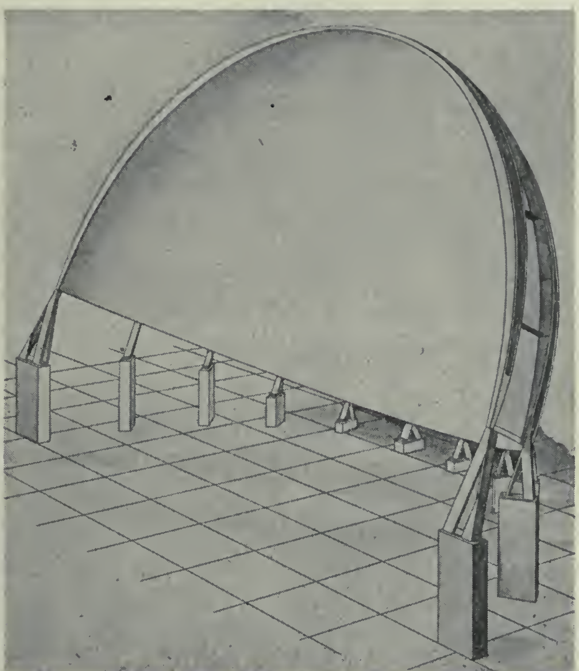

FIG. 2. Perspective view of spherical screen upon which scene is projected.

vertical, are nearly those encompassed by the normal human eye, and the angular relationships of any object, fixed or moving, on the screen are the same as those seen by the eye in actuality. Thus, the requirements of peripheral vision and movement perspective are satisfied.

In the photography, the size and atmospheric perspectives are reproduced. Therefore, the observer finds himself surrounded by a normal visual effect. The success of the curved screen process in accomplishing this is evident to anyone who has ever seen it.

For gunnery training purposes, a picture of the desired target, say an airplane, is produced. To the observer this target does not remain more or less fixed upon a single square screen covering only a

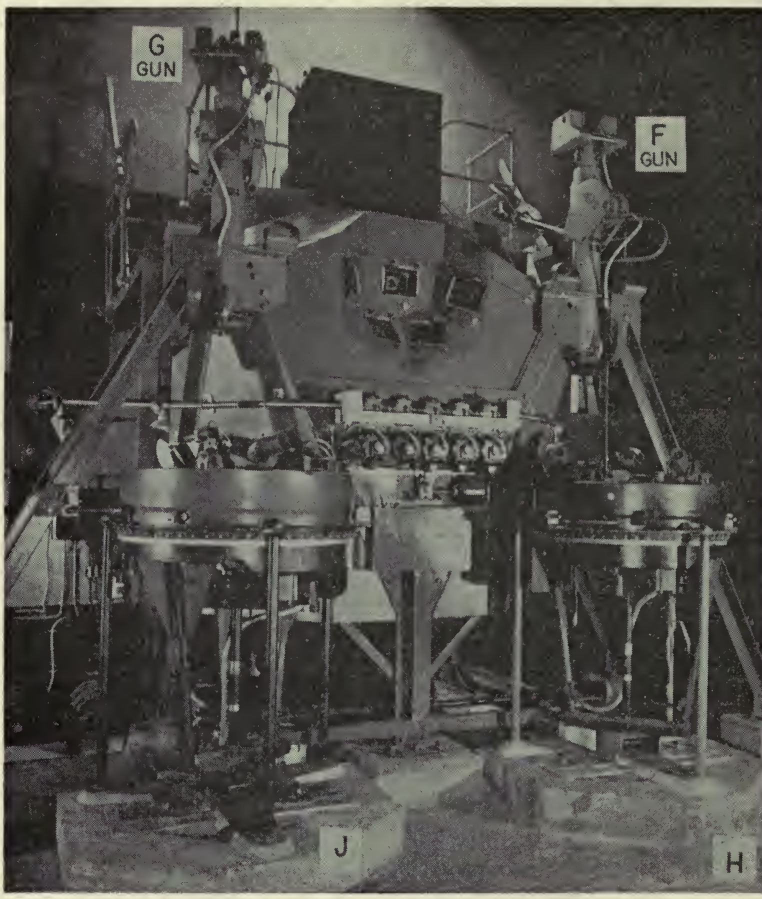

FIG. 3. Front view of trainer showing method of mounting and grouping of guns and turrets around the projection unit.

small angle but moves within his field of vision in an entirely normal manner thus enabling him to exercise his judgment of distance and motion as though he were in the field.

The observer is placed behind a dummy gun, located near the optical center of the screen, with which he attempts to hit the target.

By means of suitable apparatus described later, when the trigger of the gun is pulled, and the gun is aimed so that a hit would be made, this fact is instantly announced audibly in the gunner's earphones. This enables the person being trained to make an immediate mental note of the judgment and actions which led to success. In this way the Waller flexible gunnery trainer not only reproduces for the observer any desired environment and target, but also correctly simulates conditions of firing in a way that otherwise could only be found in actual combat. Since anything can be produced on the screen that can be photographed, and since operation of the trainer is independent of weather, time, and the availability of actual equipment, it offers a valuable means of training in preparation for and supplementing actual firing.

In order to cover a screen of 150 deg in width by 75 deg in height with motion picture projection, it was found necessary to have 5 projectors to obtain sufficient light on the screen. This dictated the number of cameras needed to take the pictures.

The camera consists of five 35-mm motion picture cameras synchronously driven and operating as a single unit. This unit has been kept sufficiently small and light so that it can be mounted in the gun or turret positions available on bombers, or be used on a tripod ashore or afloat. The cameras are arranged to cover, to the best advantage, a spherical angle of 150 deg by 75 deg, and each one covers approximately a fifth of this total image. By operating the camera unit in a gunner's position, it photographs what he would see from this same position. In the trainer, these pictures are projected on a spherical screen of the same total angles by means of 5 projectors which are arranged in the same relative positions as the cameras. They reproduce the picture as photographed, that is, as if the gunner had been in the same position which the camera occupied.

The Screen.—The screen is shown as a section of a hollow sphere of 20-ft radius. The supporting framework is made of plywood, *I*-beams and intercostals. The frame is covered with preformed plywood panels that are screwed in place. The projection surface of the screen is given a special semispecular finish which reflects light principally to the center, where the gunners are placed. By doing this, it minimizes the degradation of the projected images by cross reflection from one part of the screen to another.

Arrangement of Dummy Guns.—Placed at even distances around the center line of the projectors and the center of the screen are 4

dummy guns shown in Fig. 3. Each gun is mounted on a heavy tubular mount and is free to train and elevate so as to cover the screen. On the outside of the mount is a bearing for a seat which slides on 2 tubes so that it may be adjusted for men of different heights. The seat swings on a horizontal axis and is supported by heavy spiral springs which are also adjustable for varying weights of men. The seating arrangement gives full flexibility so that a gunner can keep his eye in line with the sight.

Each gun is provided with a pair of handles, the right one containing a trigger. When the trigger is pulled, the handles are vibrated by a pair of motors in the dummy gun, simulating the recoil of a 50-

FIG. 4. Sighting the target through the Mark *9* gun sight.

caliber gun. The instructor can disconnect the vibrator circuit if he so desires. On each gun in the original model is mounted a Mark *9* collimator sight. Fig. 4 shows what the gunner sees when he looks through his sight at the target in the field.

Subsequently, the trainer has been adapted to train men for sighting with Sperry and Martin waist-turrets, Sperry ball turrets, G. E. fire control stations, as well as several different mountings for 50-caliber and 20-mm guns, with and without lead-computing sights, and the Navy Mark *51* Director. Various combinations of these devices were installed on individual trainers as required. For training crews for the *B-29*'s, 3 pedestal-type G. E. Directors and one ring-type director are used.

Firing at Target.—As the gunner looks through the sight and follows the target the resulting movement of the gun, in train and in elevation, is transmitted, as shown in Fig. 5, by a pair of light

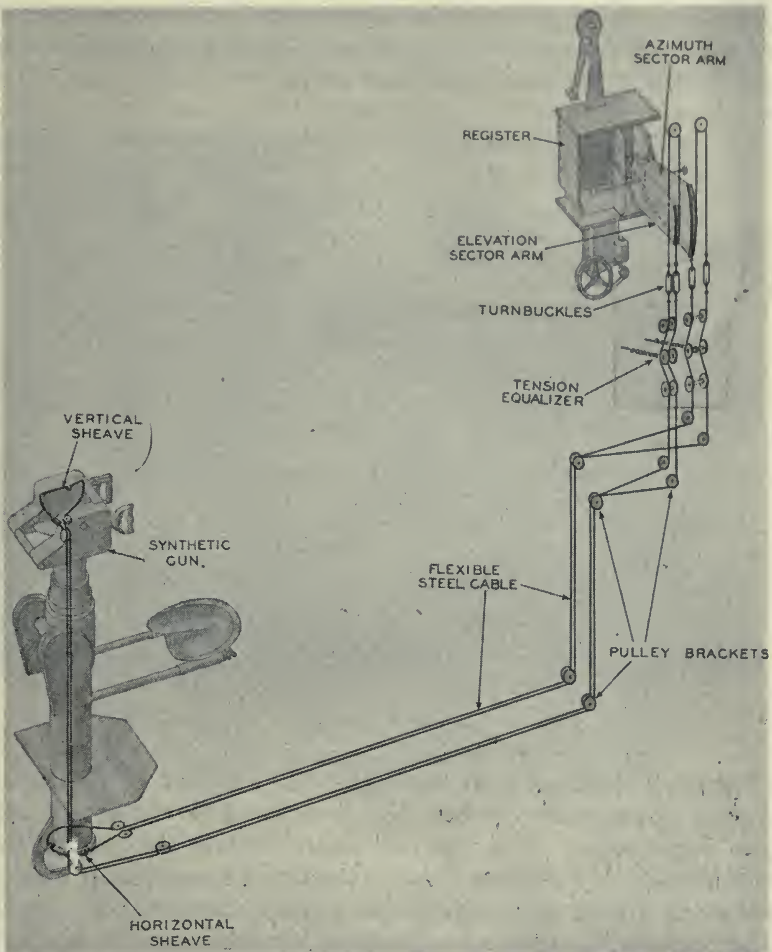

FIG. 5. Schematic drawing showing flexible steel cable system from gun to register.

flexible steel cables running over ball-bearing rollers to train and elevate lever arms in the unit called the "register." Each pair of cables is kept under constant balanced spring tension so that stretch

or expansion and contraction from temperature changes have no effect on its accuracy.

The lever for train and the lever for elevation each connect with opaque masks having a transparent pattern of 2 fine lines. These masks slide horizontally across the face of an aim scoring film in the register unit associated with each gun. Figs. 6, 7, and 8 show details of linkage and scanner bars and masks.

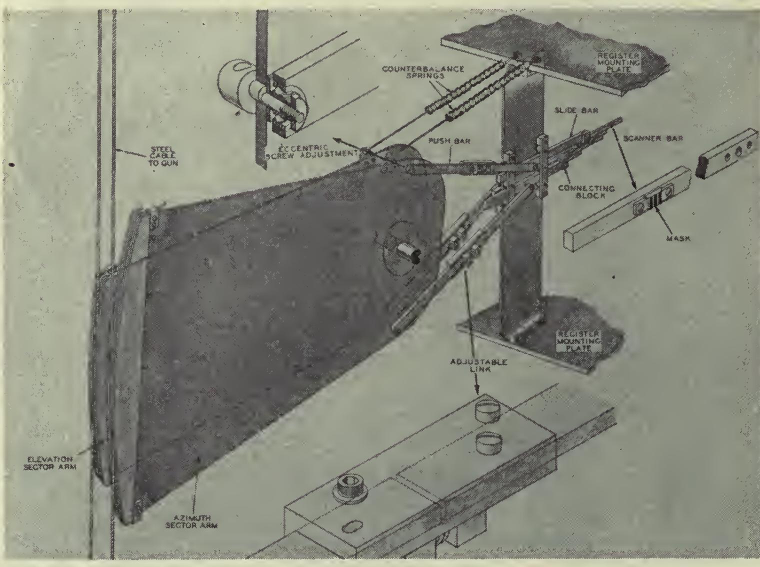

FIG. 6. Close-up of sector arm to scanner bar assembly.

Scoring Mechanism in Register.—The function of the register unit is to determine whether the gun is aimed at any instant to hit the target plane. It is this unit which receives the existing train and elevation from the gun, and if the aim is correct, it provides the means of sending electrical impulses to the instructor's console where the hit recording counter for each gun is located.

The register is similar to one of the screen projectors and the film used in the register operates in step with the screen picture films—at a speed of 24 pictures per sec. The film used in the register is not a picture film, as may be seen from Fig. 8, but is a hit scoring film specially prepared as described under the scoring machine. There is a frame of register film to correspond to each frame of picture film.

The register film is opaque and on each frame of the film are small transparent areas. The areas are so spaced that they represent the position at which the gun should be aimed to hit the target in the position shown by the corresponding picture frame. When the gun is pointed at the correct point of aim, transparent areas of the masks which the levers move will then register with the transparent areas in the film. This allows the light in the register projector to be transmitted to a photocell which, through an amplifier and relay, actuates the hit counter mounted in the instructor's console.

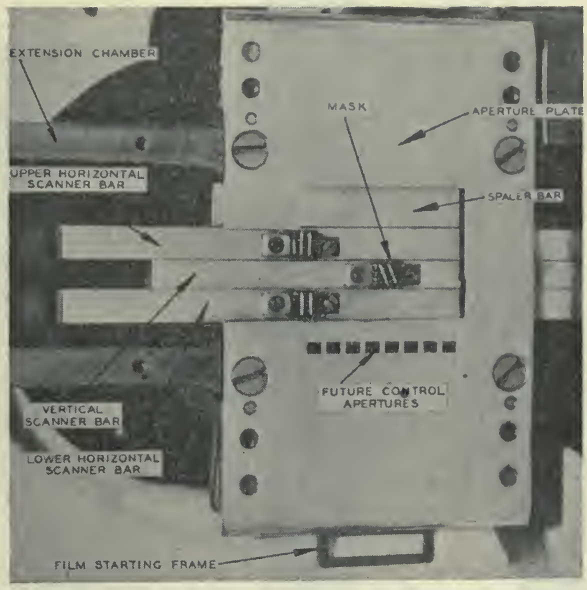

FIG. 7. Close-up view of scanner bar and gate assembly.

Each time the gunner pulls the trigger one burst for his gun is recorded on the corresponding burst counter on the instructor's console. At the same time, the bullet counter for his gun will record the number of bullets that would be fired during the length of time in which he holds the trigger down. If the gunner has his gun pointed at the correct point of aim when he pulls the trigger, he will hear a high-pitched tone in his earphones instantaneously and he will score as many hits as the number of bullets fired while he maintained the correct point of aim. If the gunner is not on the correct point of aim

when he pulls the trigger, he will still score the burst and the bullets fired but no hits.

On trainers adapted for devices where range and aim are fed in separately, 5 counters are used. The fourth records the number of

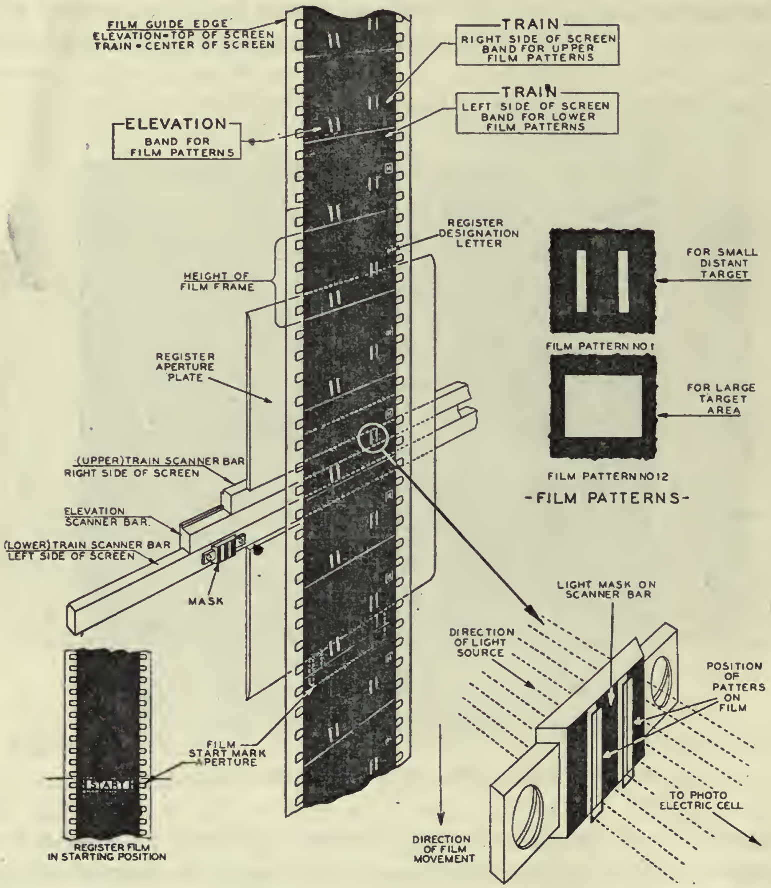

FIG. 8. Schematic drawing showing register film in relation to scanner bars and method of registering film for scoring.

bullets fired while the gunner is putting in the correct range, and the fifth the number of bullets fired while he is aiming correctly. On these trainers the hit counter scores only when both range and aim are scored simultaneously.

In order that the scoring on this machine may represent actual combat conditions, the scoring film in the register unit may have different-size transparent areas to allow for different-size vulnerable areas and targets, or to allow for the area of the cone of gun dispersion. These areas may be placed on the scoring film at different distances apart. If they are on every other frame, they will record hits at the rate of 720 per min; if on every fourth frame, at 360 per min, *etc.* By using this method, the gunner will not only score hits in proportion to his accuracy of aim but he will also score hits in the proportion which the vulnerable area of the target is to the area of the cone of fire at the

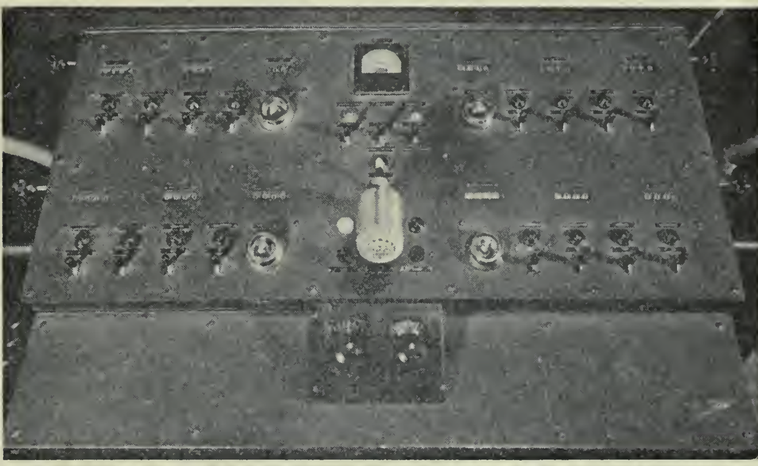

FIG. 9. Close-up view of the control panel on the instructor's console.

distance of the target. That is, if the target at 600 yards has a vulnerable area of 30 sq ft, and the area of the cone of fire is 300 sq ft, only one-tenth of the number of bullets fired would hit the target. Both of these factors are taken into consideration and the scoring gives a real indication of the man's ability as a gunner. Some branches of the Armed Services desired to omit these features and for them a constant angular tolerance of aim was used and all hits recorded. By using film for the production of the register bands, great flexibility is obtained.

Instructor's Console.—The instructor's console is mounted to the upper forward portion of the structural framework, above the 5 projectors. From his position at the console, shown in Fig. 9, the

instructor may view the entire screen and the 2 upper gun positions. The console has the following general controls and indicators:

(*a*) A running time meter to indicate total hours the trainer has been run.
(*b*) Switch to illuminate counters when house lights are off.
(*c*) A "still" button which allows instructor to hold pictures on screen for 5 min so that he may point out errors students are making in their aim.
(*d*) A "start" button.
(*e*) A "stop" button.
(*f*) Switch to permit talking to all 4 students at once.
(*g*) Projection room signal light to indicate "ready."
(*h*) Switch to communicate with office or projection room.
(*i*) Microphone head to contact students or projection room.
(*j*) Intercommunicating telephone with projection room.

In addition, 3 counters and the following controls are provided for each of the 4 gun positions:

(*a*) Total number of rounds fired.
(*b*) Number of bursts fired.
(*c*) Number of hits obtained.
(*d*) Pilot light which flashes as each hit is scored.
(*e*) Microphone switch so instructor can talk to individual gunner.
(*f*) Vibrator switch by which vibrators on individual guns may be disconnected.
(*g*) Aim projector switch which shows a one-inch diameter ring of light at place on screen at which the gun is aimed. The student does not see this light, since the central spot in his own sight covers it up but it allows the instructor to see where that student is aiming. The ring is projected on the screen by small projector mounted on the gun.
(*h*) Control knob, to return counters to zero.
(*i*) Pilot lights to indicate switches "on" or "off."

The Scoring Machine.—For the preparation of the aim scoring films which are used in the registers, we have developed a special machine called the scoring machine. This machine consists of the following parts:

(*a*) Five projectors for projecting the films one frame at a time.
(*b*) A 10-ft radius screen laid off in degrees of train and elevation on which these pictures are projected and analyzed.
(*c*) Four pointers in the same relative positions occupied by the guns on the trainer.
(*d*) Four cameras connected to these pointers for making the original negatives from which the scoring films are printed.

On this scoring machine, the pictures are analyzed and a plot is made showing the range for each frame of film, that is, each $^1/_{24}$ sec.

Simultaneously, a record is made of the angle of the target, in both train and elevation, in relation to the gun-carrying plane. A record is kept by the camerman, who makes the original negative, of the air speed and altitude of the gun-carrying plane. With all this information, the Aberdeen Tables give us the time of flight of the bullet. Knowing how many twenty-fourths of a second it will take the bullet

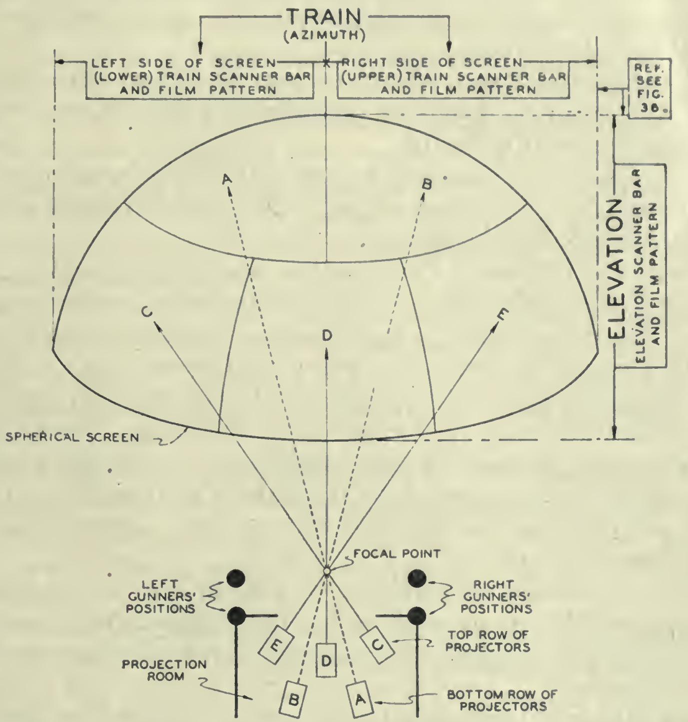

FIG. 10. Schematic plan showing method of projecting mosaics on the screen.

to reach the target, we then aim the 4 pointers, which represent the 4 gun positions, at the picture which is that many twenty-fourths of a second, or frames of film, later. This gives the correct angular lead. By then displacing each pointer the number of gunnery mils in both train and elevation which the tables give as the ballistic corrections, we have the correct point of aim.

By a system of cables and levers similar to those connecting the gun and its register, each pointer is connected to a scoring camera.

This camera makes a master negative scoring band for its gun. When the scoring band is run in synchronism with the picture print from which it has been made, it will record, to within a few gunnery mils, the correct point of aim for the moving target shown on the picture film.

Projector Unit.—The projector unit is a group of 5 Century projectors operating in synchronism as a single mechanism. All are of the same mechanical design and each projects a portion of the whole picture upon the screen.

The optical axis of each projector passes through a common point, the focal point of the screen, and radiates to 5 different areas on the screen, as illustrated in Fig. 10.

The projectors are designed for use with 35-mm motion picture film, operating at 24 frames per sec. The running time of a 3000-ft reel is approximately 33 min.

A heat shield, which is a circular heat-absorbing Aklo glass filter and associated mechanisms, is located close to the rear wall of the projector. It is mounted on a counterbalanced pivoted arm and operated by a solenoid in conjunction with a limit switch which is related to a sequential circuit. The purpose of the heat shield is to absorb and reduce the heat at the aperture in the film trap and protect the film when still pictures are being projected. Incidentally, during this period the radiant heat from the lamp is also automatically reduced by dimming to a degree but still providing sufficient light for still picture projection.

When the solenoid operating the heat shield is energized, it pulls the heat shield into its place just back of the condensing lens assembly, where it absorbs a portion of the radiant heat from the lamp before it reaches the film.

Lamp House.—A cylindrical lamp house is mounted on the rear of the shutter guard. A large hinged door extending half way around the housing permits access to the interior for lamp replacements and optical adjustments. It accommodates a 2100-w incandescent filament lamp as the light source for the projector.

An inner tube, which surrounds the lamp, is part of the cooling system. It serves to direct an air stream all around the lamp house to carry away the heat generated by the lamp.

Cooling System.—The system of forced air circulation in the lamp house has been devised to remove normal generated heat that would endanger the film in the projector and to provide cool operat-

ing conditions. It includes the assembly of distribution ducts and air tubes associated with the projector. They in turn are connected to an air supply and exhaust system provided in the building.

The air is forced in at the top of the lamp house, streams past the full length of the lamp all around the bulb as directed by the air tube within the house, and the heat is carried off through the exhaust at the bottom of the house to be dissipated at a distant point.

An additional cooling system is provided for the film. It is devised to force a high-velocity sheet of air downward on both sides and over the entire surface of the film in the film trap. The air is distributed through a forked inlet pipe connection on the driving side of the projector and passes through the center wall to the film or operating side. One tube leads to the nozzle on the film trap, the other to nozzle on the film gate. After the cooling curtains of air flow past the film surfaces, they circulate about in the immediate vicinity of the mechanisms in the projector.

Main Drive.—Each projector is driven by its own electric motor, but all motors are mechanically coupled together and held in synchronism by an arrangement of beveled gears on a common synchronizing shaft that keeps all projectors running at a speed of 24 frames of film per sec.

Framing Motor.—An additional motor called the framing motor, mechanically connected with the synchronizing shaft, serves to bring the projector mechanisms to a stop with the film in frame and shutters open so that the still picture projected is properly composed on the screen.

Photoelectric Controls.—The photoelectric controls of the trainer, designed by W. Robert Dresser, are most elaborate and although not covered here could easily be the subject of an entire paper.

60th SEMIANNUAL

TECHNICAL CONFERENCE

HOLLYWOOD-ROOSEVELT HOTEL
Hollywood, California

OCTOBER 21–25, 1946

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HOTEL RESERVATIONS AND RATES

The Hollywood-Roosevelt Hotel, Hollywood, Calif., will be the Conference Headquarters, and the hotel management extends the following per diem room rates, European plan, to SMPE members and guests:

Room with bath, one person	$4.40–5.50
Room with bath, two persons, double bed	$5.50–6.60
Room with bath, two persons, twin beds	$6.60–7.70

Desired accommodations should be booked *direct* with Stewart H. Hathaway, Manager of the hotel, who advises that no parlor suites will be available unless confirmed by him. All reservations are subject to cancellation prior to October 14, and *no reservations will be held after 6:00 p.m.* on the anticipated date of arrival unless the hotel management has been advised otherwise.

HOUSING COMMITTEE

An acute housing condition exists in Hollywood and it is expected that most of the available reservations at the Hollywood-Roosevelt Hotel will have been taken by the time this issue of the JOURNAL reaches the membership. In order to be of assistance to members desiring room accommodations, the Pacific Coast Section has set up a Housing Committee under the Chairmanship of Past-President Herbert Griffin.

The Housing Committee expects to mail a return post card to all members outside of the Hollywood area on which the member may state whether he desires room accommodations and for what length of time. The returned cards will be checked against available reservations and an effort will be made to place Eastern and Midwestern members who plan to attend the Conference. However, the demand is very apt to exceed the supply and reservations will be made on the basis of "first come, first served." It will be of assistance to all concerned to have the cards returned as quickly as possible.

RAIL, PULLMAN, AND AIR ACCOMMODATIONS

SMPE members and guests who have received confirmed room reservations, should then consult local transportation agents as early as possible, and book their desired transportation accommodations immediately.

REGISTRATION

The Conference Registration Headquarters will be located in Room 201 on the mezzanine floor of the hotel, where Luncheon and Dinner-Dance tickets can be procured prior to the scheduled dates of these functions. Members and

guests are expected to register. The fee is used to help defray Conference expenses.

BUSINESS AND TECHNICAL SESSIONS

Day sessions will be held in the hotel, and evening sessions at locations away from the hotel, which will be listed in the preliminary, and final printed Conference programs.

Authors who are planning to present papers at the 60th Semiannual Technical Conference should mail the title of their paper to the West or East Coast Chairman of the Papers Committee, or to the Society's New York Office, as soon as possible. As a prerequisite to inclusion on the program, authors' abstracts must be received by the Papers Committee by Sept. 1. Complete manuscripts *must* be submitted by Oct. 1, 1946. Only through your cooperation can a preliminary program be drafted early enough for publication in the industry trade papers and mailing to the membership at least a month prior to the Conference.

GET-TOGETHER LUNCHEON AND DINNER-DANCE

The Society will again hold its regular pre-war social functions and accordingly a Get-Together Luncheon is scheduled in the California Room of the hotel on Monday, October 21, at 12:30 P.M. The luncheon program will be announced later. Members in Hollywood and vicinity will be solicited by a letter from S. P. Solow, Secretary of the Pacific Coast Section, to send remittances to him for the Conference registration fee and luncheon tickets. Ladies are welcome to attend the luncheon.

The 60th Semiannual Dinner-Dance will be held in the California Room of the hotel on Wednesday evening, October 23, at 8:30 P.M. Dancing and entertainment. (Dress optional.) A social hour for holders of Dinner-Dance tickets will precede the Dinner-Dance between 7:15 P.M. and 8:15 P.M. in the Hotel Terrace Room (Refreshments).

LADIES' PROGRAM

A reception parlor for the ladies' daily get-together and open house with Mrs. H. W. Moyse as hostess will be announced on the hotel bulletin board and in the final printed program.

Ladies are welcome to attend technical sessions of interest, also the Luncheon on October 21, and the Dinner-Dance on October 23. The Conference badge and identification card will be available to the ladies by applying at Registration Headquarters.

The ladies' entertainment program will be announced later.

MOTION PICTURES AND RECREATION

The Conference recreational program will be announced later when arrangements have been completed by the local committee. Identification cards issued only to registered members and guests will be honored at the *deluxe* motion picture theaters on Hollywood Boulevard. Those desiring other recreation during the Conference should consult the hotel bulletin board or inquire at Registration Headquarters.

Technical Sessions Scheduled

Monday, October 21, 1946

Open Morning.

10:00 a.m. *Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Luncheon and Dinner-Dance tickets.

12:30 p.m. *California Room:* **SMPE Get-Together Luncheon.** Program announced in later bulletins.

2:00 p.m. *Aviation Room, Hotel Mezzanine Floor:* **Opening business and Technical Session.**

8:00 p.m. **Evening Session:** Location to be announced later.

Tuesday, October 22, 1946

Open Morning.

10:00 a.m. *Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Dinner-Dance tickets.

2:00 p.m. *California Room:* **Afternoon Session.**

8:00 p.m. **Evening Session:** Location to be announced later.

Wednesday, October 23, 1946

9:30 a.m. *Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Dinner-Dance tickets.

10:00 a.m. *California Room:* **Morning Session.**

Open Afternoon.

7:15 p.m. *Hotel Terrace Room:* A social hour for holders of Dinner-Dance tickets preceding the Dinner-Dance (Refreshments).

8:30 p.m. *California Room:* **60th Semiannual Technical Conference Dinner-Dance.** Dancing and entertainment. Program will be announced later.

Thursday, October 24, 1946

Open Morning.

1:00 p.m. *Room 201, Hotel Mezzanine Floor:* **Registration.**

2:00 p.m. *California Room:* **Afternoon Session.**

8:00 p.m. **Evening Session.** Location to be announced later.

Friday, October 25, 1946

Open Morning.

2:00 p.m. *California Room:* **Afternoon Session.**

8:00 p.m. **Evening Session.** Adjournment of the 60th Semiannual Technical Conference. Location to be announced later.

Note: All sessions during the 5-day Conference will open with an interesting motion picture short.

Important

Because of the existing food problem, your Luncheon and Dinner-Dance Committee must know in advance the number of persons attending these functions in order to provide adequate accommodations.

Your cooperation in this regard is earnestly solicited. Luncheon and Dinner-Dance tickets can be procured from W. C. Kunzmann, Convention Vice-President, during the week of October 13 at the Hollywood-Roosevelt Hotel.

All checks or money orders for Conference registration fee, Luncheon and Dinner-Dance tickets should be *made payable* to W. C. Kunzmann, Convention Vice-President, and *not* to the Society.

W. C. KUNZMANN
Convention Vice-President

SOCIETY ANNOUNCEMENTS

MIDWEST SECTION MEETING

A large audience of Midwest Section members and guests was addressed by Frank E. Carlson of General Electric Company, Nela Park, Cleveland, who discussed "Tungsten Filament Light Sources" at a meeting held in the Paramount Preview Theater, Chicago, June 20.

Future improvements in tungsten sources for projection will not supply such gains and output as achieved previously through higher efficiency. Mr. Carlson suggested that engineers should choose the correct source size for a particular system of projection optics by making practical use of the reversibility of the optical systems. Diffuse illumination of the objective will allow the image size to be measured at the filament position.

A summary of the influence of filament coiling on sound reproduction systems was given.

The meeting concluded with the showing of selected portions of the German Agfa negative-positive process color film, *The Golden City*. Discussion of the film brought out the fact that the cyan color was apparently suppressed either for esthetic reasons or because of technical difficulties. The increased resolution of the print was favorably received.

The first meeting of the fall series is scheduled for September 12, at 8:00 P.M. in Western Society of Engineers' Hall, 205 West Wacker Drive, Chicago. All Society members in the area who are not now receiving Midwest Section meeting notices should communicate with Robert E. Lewis, Secretary-Treasurer, Armour Research Foundation, Chicago 16, Ill.

PACIFIC COAST SECTION MEETING

Captain E. M. Senn, U. S. Navy, and Captain William C. "Bill" Eddy, U. S. Navy, retired, addressed a joint meeting of the Pacific Coast Section and the Institute of Radio Engineers held on June 10 in the Walt Disney Studio Theater,

Burbank, Calif. The meeting was opened with a screening of an interesting Navy film showing the use of radar in naval engagements.

Captain Senn described the Navy's extensive electronics training course, which is accredited at Purdue University for 2 years toward an electrical engineering degree. He also pointed out the Navy's serious need for qualified young men to maintain Navy electronic equipment.

Captain Eddy discussed some of the wartime electronic devices which were so vital in bringing the war to its successful conclusion. He conducted an open forum during his address answering many interesting questions.

Captain Eddy has returned to his civilian activity as director of the Balaban and Katz television station in Chicago, and gave a description of the new 700-ft antenna structure now under construction.

A large number of Navy personnel swelled attendance of the combined meeting to over 350.

EMPLOYMENT SERVICE

POSITIONS OPEN

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

Motion picture studio in Bombay, India, has positions open for professional motion picture camerman with studio and location experience; sound recording engineer experienced in installation, maintenance and operation of recording equipment; motion picture processing laboratory supervisor; and professional make-up artist. Five-year contracts at favorable terms are offered to those qualified. Write or cable direct to Personnel Manager, Dawlat Corporation Ltd., Patel Chambers, French Bridge, Bombay 7, India, giving experience, etc., in detail.

New film production unit to be located at Athens, Georgia, needs film editor-writer and film director. Experience in 16-mm as well as 35-mm production desirable. Southern background or interest in South preferred but not essential. Write giving full details of experience, etc., to Nicholas Read, The National Film Board, Ottawa, Canada.

POSITIONS WANTED

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Honorably discharged veteran with 10 years' experience in projection and installation of projection and sound equipment, both for booth and back-stage. Prefer to locate in California, Oregon or Nevada. For additional details write F.A.N., Box 113, Holley, Oregon.

Cameraman, honorably discharged Army veteran, desires re-enter industrial, educational production with independent producer or studio. Experienced in 35- and 16-mm color and black-and-white. References and complete record of experience available. Write, wire or telephone T. J. Maloney, 406 Oak St., Ishpeming, Mich. Telephone 930.

Sound Recordist. Former Signal Corps sound instructor and Army Pictorial Service newsreel recordist-mixer, 35-mm equipment. Honorably discharged veteran, free to travel. Write Marvin B. Altman, 1185 Morris Ave., New York, N. Y. Telephone Jerome 6-1883.

16-mm Specialist. Honorably discharged veteran with many year's experience, specializing in 16-mm. Linguist. Available for special assignments. Write J. P. J. Chapman, ARPS, FRSA, The Huon, Branksome Hill Road, Bournemouth, England.

Cameraman. Veteran honorably discharged from Air Force Motion Picture Unit desires to re-enter industrial, documentary, or educational film production. Experienced in 35- and 16-mm, sound, black-and-white and color cinematography. Single, willing to travel. Write S. Jeffery, 2940 Brighton Sixth St., Brooklyn 24, N. Y. Telephone Dewey 2-1918.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 | AUGUST, 1946 | No. 2

CONTENTS

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JOURNAL
OF THE
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Vol 47 AUGUST, 1946 No. 2

REPORTS OF SMPE COMMITTEES

REPORT OF THE COMMITTEE ON MOTION PICTURE INSTRUCTION*

JOHN G. FRAYNE**

The Committee on Motion Picture Instruction was formed in October 1945, with the aim and purpose of providing the Society with a list of the various institutions, colleges, and universities that teach courses on motion pictures. The Society would then list these sources for education in motion pictures, enumerating courses that are taught at each institution, thereby permitting the Society to furnish concrete information in answer to inquiries from individuals seeking information on where such courses and instruction might be obtained.

After some preliminary correspondence between the members, a questionnaire was drawn up and approved for submission to educational institutions of technical school or college grade. A copy of the questionnaire is attached as an appendix to this report. It will be noted that it requested information from each institution on the subjects listed below:

(*1*) Cinematography (including color)
(*2*) Photography (including color)
(*3*) Sound Recording
(*4*) Motion Picture Film Editing
(*5*) Motion Picture Projection
(*6*) Motion Picture Distribution
(*7*) Economic Problems in Motion Picture Production and Exhibition
(*8*) Film Processing—still
(*9*) Film Processing—motion picture
(*10*) Miscellaneous

The questionnaire was sent to 155 institutions of higher learning scattered throughout the United States. To date, replies have been

* Presented May 8, 1946, at the Technical Conference in New York.

** Chairman.

received from 102, or approximately 66 per cent of those sent out. Of this number, 60 were universities, 32 were colleges, 8 were technical schools, one was a military academy, and one was an Armed Forces institute. The information has been broken down into courses which are listed below in the order of their appearance on the questionnaire:

CINEMATOGRAPHY (INCLUDING COLOR)

Name of College	Courses	Semester Hours	Credits
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Motion Pictures *1-2*	3 per wk	6
Oregon State College Corvallis, Ore.	Educational Cinematography (Summer Session only)	3 term hr (2 sem. hr)	3 (2)
University of Denver Denver, Colo.	Motion Picture Making	2 quarter hr	2
Ohio State University Columbus, Ohio	Cinematography	2	2
University of Southern California Dept. of Cinema 3551 University Av. Los Angeles, Calif.	Cinema *115ab*, Cinema *165ab*, and others (see bulletin)	1st yr, 8 hr per wk 2nd yr, 8 hr per wk	8 units 8 units

PHOTOGRAPHY (INCLUDING COLOR)

Name of College	Courses	Semester Hours	Credits
Iowa State College Ames, Iowa	1. Physics *316* 2. Physics *650*	1. $4^1/_2$ 2. 3 or more	These 2 courses are to develop photography in scientific fields
University of Oregon Eugene, Ore.	Rudiments of Photographic Journalism	$1^1/_2$	2 term hr
Oberlin College Oberlin, Ohio	In Dept. of Chemistry (Photography)	Lab.—1 or 2 3-hr periods per wk	2 or 3 hr
Baylor University Waco, Tex.	Photography	$3^1/_2$	
University of Detroit Detroit, Mich.	*P41b*	3 hr or more per wk for 1 sem.	2
University of Minnesota Minneapolis, Minn.	News Photography Photography	3 quarter hr per wk 5 quarter hr per wk	3 3
Gustavus Adolphus College St. Peter, Minn.	*211* Photography *212* Advanced Photography	2 2	2 2

Name of College	Courses	Semester Hours	Credits
Drake University Des Moines, Iowa	News Photography	2	2
College of Emporia Emporia, Kan.	Photography in Physics Dept.	Sem. I—2 hr	2 hr
University of Colorado Boulder, Colo.	Photography	2	2
Brigham Young University Provo, Utah	Photography		
	Elementary	5	5
	Advanced	3	3
State College of Washington Pullman, Wash.	Photography—in planning stage at present		
Northwestern University Medill School of Journalism Evanston, Ill.	Elements of Photography	4 quarter hr	4
	Press Photography	4 quarter hr	4
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Motion Pict. *3-4*	2 per wk	4
Colgate University Hamilton, N. Y.	Photography	3	3
Miami University Oxford, Ohio	Elementary Photography (Still)	2	2
	Advanced Photography (Still)	4	3
Oregon State College Corvallis, Ore.	*Ph 161*—Rudiments of Photography	2 term hr (1.33 sem. hr)	2 (1.33)
	Ph 361 (Hand Camera)	3 term hr (2 sem. hr)	3 (2)
	Ph 362 (Commercial)	3 term hr (2 sem. hr)	3 (2)
	Ph 363 (Composition Enlarging)	3 term hr (2 sem. hr)	3 (2)
	Ph 461, 462, 463—Advanced Photography (Color, Photomicrography, Microscopic Motion Pictures)	3 term hr (2 sem. hr)	3 (2)
University of Idaho Moscow, Idaho	"Photographic Technique" (Zool. *151-152*). Does not include motion picture but includes color-correct photography and some color photography	Sem. I — 3 hr	3
		Sem. II — 2 hr	2
St. Olaf College Northfield, Minn.	Photography & Art	4 hr	2 sem.

Name of College	Courses	Semester Hours	Credits
Ohio State University Columbus, Ohio	3 courses	3 (each course)	3 (each course)
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	Cinema *90, 91, 92;* Cinema *121ab* Cinema *50ab* will replace *90, 91* (Color—begins 1946)	Each course 4 hr per wk 7 hr per wk	2 units per course 3 units

It will be noted that 21 schools report courses in photography. These appear to range all the way from elementary photography through news photography to the more scientific aspects of the subject, such as photomicrography. It will be noted, however, that in none of the replies is there any indication that photography is considered as a major subject leading to a degree. On the other hand, it appears to be a minor subject associated with a wide variety of major courses.

SOUND RECORDING

Name of College	Courses	Semester Hours	Credits
Georgia School of Technology Atlanta, Ga.	Sound Recording	Part of course in public speaking	
State College of Washington Pullman, Wash.	None, except in courses offered in radio techniques		
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Motion Pictures *9-10*	2 per wk	4
Oregon State College Corvallis, Ore.	Ed. *533*—Correlation of radio recordings with visual aids (Occasionally given in summer session. Occasionally a few students are trained on an apprenticeship basis in connection with radio station *KOAC*—very fragmentary.)	3 term hr (2 sem. hr.)	3 (2)
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	Cinema *140*	3 hr per wk	2 units

Only five schools list any courses in sound recording, and two of these can only be considered as dealing with operation of equipment rather than study of the fundamental engineering problems involved in sound recording. In fact, it is very doubtful that any strictly technical courses in this most important field are offered in any of the higher institutions of learning in the United States.

MOTION PICTURE FILM EDITING

Name of College	Courses	Semester Hours	Credits
New York University Dept. of Motion Pict. Washington Square New York, 3 N. Y.	Motion Pictures *31*	2 per wk	2
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	Cinema *135*	3 hr per wk	2
Antioch College Yellow Springs, Ohio	Motion Picture Film Editing	20 wk	5

MOTION PICTURE PROJECTION

Name of College	Courses	Semester Hours	Credits
University of Kansas Lawrence, Kan.	Study of the history, technique, art, and the social and educational significance of the motion picture	2	2
Pennsylvania State College State College, Pa.	Teach projection but not for credit. 16-mm only.	None	
University of Kentucky Lexington, Ky.	Given both informally upon request of individuals and included in educational audio-visual instructional aids courses.		
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Included in Motion Pictures *3-4*		
Antioch College Yellow Springs, Ohio	Classes conducted by students under extra-curricular committee.		

It will be noted that five institutions indicate some kind of courses in motion picture projection. However, the courses offered either give no university credit or are considered a part of other courses in motion pictures or audio-visual instruction.

MOTION PICTURE DISTRIBUTION

Name of College	Courses	Semester Hours	Credits
Pennsylvania State College State College, Pa.	Motion Picture Dist.		
University of Kentucky Lexington, Ky.	Included in graduate courses on audio-visual aids in instruction. Commercial distribution for entertainment is not included.		
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Motion Pictures *19-20*	2 per wk	4
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	Cinema *150*	2 hr per wk	2 units

ECONOMIC PROBLEMS IN MOTION PICTURE PRODUCTION AND EXHIBITION

Name of College	Courses	Semester Hours	Credits
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Motion Pictures *19-20*	2 per wk	4
University of Denver Denver, Colo.	Courses planned for 1946–1947 in School of Commerce		
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	Cinema *250ab*	2 hr per wk for 2 sem.	2 units per sem.

FILM PROCESSING—STILL

University of Detroit Detroit, Mich.	Film Processing—Still	As a part of the Lab. work, *etc.*, of General Photography	
State College of Washington Pullman, Wash.	In Planning Stage		
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	Covered in Cinema *90*, *91*, and *92*		

FILM PROCESSING—MOTION PICTURE

Oregon State College Corvallis, Ore.	Included (16 mm) in courses in Photography		

MISCELLANEOUS

Baylor University Waco, Tex.	Course in Visual Ed.	$3^1/_3$	
Pennsylvania State College State College, Pa.	Visual Education—Ed. *423* Lab. in visual and other aids	2	1
	Ed. *424* Visual & other sensory aids in education	1 or 2	1 or 2
University of Michigan Ann Arbor, Mich.	*B-133* Visual-Sensory aids in education		2 hr
	B-300 Research Seminar		Credit arranged
Kansas State College of Agriculture & Applied Science Manhattan, Kan.	"We make a few films for public relations and instructional purposes but offer no instruction in any technical phase of the motion picture industry, although we do offer a course in visual instruction and we have three courses in still photography. We would be glad to have syllabi and other information which might be useful in formulating plans for technical course work."		

Name of College	Courses	Semester Hours	Credits
Louisiana Polytech. Institute Ruston, La.	"I am teaching a class in 'Audio-Visual Aids to Instruction.' It has to do with making effective utilization of films in the classroom. Although motion picture production, distribution, *etc.*, should concern itself with the 16-mm documentary and educational film as well as the entertainment film. I find a tendency to center all courses around the 35-mm 'Hollywood' entertainment industry. This was my observation during the past three years spent with the Army's film center in New York and observation of courses in the colleges of that city."—Robt. H. Mount, Dir. of Visual Instruction.		
Oregon State College Corvallis, Ore.	Ed. *431*—Construction and use of Visual Aids	3 term hr (2 sem. hr)	3 (2)
	Ed. *531*—Organization and supervision of visual aids (summer only)	3 term hr (2 sem. hr)	3 (2)
	I Ed. *474*—Written and visual teaching aids.	3 term hr (2 sem. hr)	3 (2)
	Wild Life Photography (a new course to be given by Dept. of Zoology)		
University of Oklahoma Norman, Okla.	Audio-visual Education: a course designed principally for teachers	2	2
University of Kansas Lawrence, Kan.	Methods and Administration of Visual Instr.	2	2
A. & M. College of Texas College Station, Tex.	"Some interest is being developed toward use of films in connection with teaching. Committee actively working on these details—I am Chairman of that Committee."—G. B. Wilcox, Head, Dept. of Educ. & Psychology		
University of Colorado Boulder, Colo.	Photochemical Physics	1	1
Otis Art Institute 2401 Wilshire Blvd. Los Angeles, Calif.	Theater & Set Design Course	Course requires 3 yr	First year basic earns 31 term pt. Total term pt. for course, 114
Pasadena Junior College East Colorado St. Pasadena, Calif.	Stage Technology	2-yr course	
	"Students completing this course are qualified to accept positions in radio, motion pictures, television, recording, and legitimate stage. In the past we have found it most helpful to use as teaching aids advertising materials such as graphs, illustrations, charts, data sheets, *etc.*, put out by the various companies supplying these fields. This enables the students to become acquainted with available equipment, its care, use, and applications, and also to receive up-to-the-minute in-		

Name of College	Courses	Semester Hours	Credits
	formation on new developments. We should appreciate being included on your mailing list to receive such materials as you may have. If possible, we should like to have this material in lots of 200 so that each student may have a copy for reference."		
Georgia School of Technology Atlanta, Ga.	Parts of courses in Physics and Elec. Eng.		
University of South Dakota Extension Division Vermillion, S. D.	Visual Instruction (During summer session)		
Harvard University Cambridge, Mass.	Audio-Visual aids to teaching	2	2
University of Wisconsin Univ. Extension Div. Madison 6, Wis.	Visual Instruction: "Designed to meet the needs of administrators, classroom teachers, supervisors, and directors of visual education. The history of visual education, relevant principles of learning, scientific studies in the field, and methods of evaluation are investigated. Individual assistance is given in co-ordinating audio-visual materials to course of study or general curriculum needs, and demonstration of tested methods of classroom use of audio-visual materials at elementary and secondary school levels in requested subject areas."		2
	Local Production of Audio-Visual Materials: "An opportunity for teachers, supervisors, and administrators actually to produce those audio-visual teaching materials which adapt themselves for production in the local school situation. Following a brief treatment of audio-visual teaching psychology and philosophy, the persons enrolled will be taken through experiences in developing poster files, bulletin-board displays, the construction of terrain models and filmstrip, slide and motion picture production. Laboratory facilities will be available to a maximum enrollment of 15. People coming into the course should have their own cameras, to be approved by the instructors. Other arrangements may be made for a limited number of interested people who own no equipment but who intend to do so."		
Cornell University Dept. of Extension Teaching and Info. Ithaca, N. Y.	"At present we give only one course in photography which is more an introduction to all phases of photographic work than anything else. It is intended to give prospective teachers an idea of the scope and methods applicable to their teaching."		
New York University Dept. of Motion Pict. Washington Square New York 3, N. Y.	Motion Pictures *91*	2 per wk	3
Boston University 84 Exeter St.	Visual Education—Mgt.	$2^1/_4$ per wk	3

Name of College	Course	Semester Hours	Credits
Boston, Mass.	Problems in Visual Ed.—Mgt.	$2^1/_4$ per wk	3
	"None of our courses limit themselves to the use of the educational motion picture although a considerable portion of the courses discuss the possibility of the motion picture in education."		
Antioch College Yellow Springs, Ohio	Aspects of the Film	12 wk	3
Massachusetts Institute of Technology Cambridge, Mass.	"MIT offers no courses that exactly fit into these categories. For example, we offer a course on color, of which color reproduction is one important aspect. In normal times we offer courses on photography and cinematography but they were temporarily discontinued because of the war."		
University of Southern California Dept. of Cinema 3551 University Ave. Los Angeles, Calif.	A.B. Degree with major in Cinema M.A. Degree with major in Cinema See Bulletins. Related courses in physics and engineering—Electronics, Recording, *etc.*		
Indiana University Extension Division Bloomington, Ind.	"At the present time, we have only one course in audio-visual aids in production, but will break this course down into 3 to 5 courses as our production program gets under way at Indiana University."		

Of the courses listed above as offered by the various institutions, few, if any, can be construed as offering technical information on a level corresponding to that of other well-established curricula. On the other hand, they appear to come under the broad heading of "Visual Education." Some of these courses do include the actual making of films, which involves the artistic as well as the technological aspects of motion picture making. Undoubtedly, students taking these courses do obtain a certain familiarity with motion picture equipment, especially of the 16-mm variety, but it is doubtful that any basic training in cinematography or sound recording is included in these visual education courses.

The results of the survey of the higher institutions of learning in the United States by the Committee indicate very clearly that the technology of motion picture making has not been given serious consideration in institutions of this caliber. While it must be admitted that courses in physics, chemistry, electrical engineering, electronics, *etc.*, offer the basic groundwork for proficiency in the various fields of picture making, it would appear that the industry has advanced to a point where training for it should be recognized as calling for special instruction in our schools and colleges. It would certainly appear

that it is high time for cinematography to be emerging from the strictly "craft" classification into that of a full-fledged profession. The modern cinematographer, it seems, should have a basic education in physics, chemistry, illumination, photography, camera design, and all the other elements that go into the work of a cinematographer. The results of the questionnaire, however, show that this condition does not exist in our American schools.

In the newer fields of motion picture activity, such as sound recording, it is hardly to be expected that formal courses in this subject should be listed at this time. It may be argued that sound recording calls for training in the basic physical and electronic sciences, and as such should be covered in the regular courses given in this field. To those of us who are familiar with the ramifications of modern sound recording for motion pictures, public address, and radio, it would seem that it is about time that specific courses leading to a degree in this most important field should be offered by some of our more progressive institutions.

It is of particular interest to the Committee that of the well-known institutions of learning in Southern California—the home of the motion picture—only the University of Southern California lists any courses in the field of motion picture making. However, these courses are pointed more toward training people for teaching similar courses in other institutions and for providing a background for those interested in the cinema rather than providing solid engineering training pointed toward the professional aspects of the industry. One would expect that here at least some attempt should be made to train young men and women for positions in what is probably the largest local industry. The failure of these institutions to do so reflects the general opinion that motion picture making is in the classification of a craft rather than a profession, and as such does not warrant the serious attention of institutions of higher learning. Another important factor is the reported difficulty of graduates from local schools finding employment in the studios, where a rigid closed shop bars employment of anybody except members of the various labor unions. It will be necessary, therefore, to secure the co-operation of the various labor unions with the local colleges in setting up high grade courses of technical instruction. Until some avenue of employment is opened to prospective graduates of these courses, there seems to be little hope of improvement in the present situation.

Appendix A

QUESTIONNAIRE
COMMITTEE ON MOTION PICTURE INSTRUCTION
SOCIETY OF MOTION PICTURE ENGINEERS

The Society of Motion Picture Engineers has organized a Committee on Motion Picture Instruction. This Committee was formed in response to numerous requests received from members of the Society, individuals outside of the Society, and members of the Armed Forces asking for information as to where educational courses might be taken which would help them gain a better understanding of the motion picture film industry, in its three major phases: namely, production, distribution and exhibition.

The following questionnaire has been prepared in an effort to procure this information, and your cooperation in completing it will be appreciated:

Name of Institution____

Address____

Check Type of Institution: University____ College____ Technical School____

Trade School____ Other____

Courses	Pre-Requisites	Semester Hours	Credits
Cinematography (including color)			
Photography (including color)			
Sound Recording			
Motion Picture Film Editing			

Courses	Pre-Requisites	Semester Hours	Credits
Motion Picture Projection			
Motion Picture Distribution			
Economic Problems in Motion Picture Production and Exhibition			
Film Processing—Still			
Film Processing—Motion Picture			
Add here any courses in topics not listed above which may have a bearing on the motion picture industry and which deal with the technical rather than the artistic phases of motion picture production and exhibition			

JOHN G. FRAYNE, *Chairman*
Committee on Motion Picture Instruction

REPORT OF THE COMMITTEE ON 16-MM AND 8-MM MOTION PICTURES*

D. F. LYMAN**

Early in 1945 this Committee, formerly called the Committee on Nontheatrical Equipment, was reorganized, principally because the chairman became Engineering Vice-President of the Society.

From the very start, there was some dissatisfaction with the former name, "Committee on Nontheatrical Equipment." It seems to us that 16-mm film, at least, is destined to become more and more theatrical, in both senses of the word. Moreover, we did not wish to have our activities confined to "equipment," nor to the 16-mm size, which was the only one mentioned in the wording of the scope of the Committee. J. A. Maurer discussed the question with the proper authorities of the Society. They gave us their permission to have the name "Committee on 16-Mm and 8-Mm Motion Pictures" proposed to the Committee in the form of a letter ballot. Affirmative votes were received from 27 of the 31 members who voted. The other four suggested alternatives that were, for the most part, similar. Hence the new name.

We needed also a new expression of the scope of the Committee because the old statement limited our activities to problems related to the *projection* of film, and to the 16-mm size, as stated above. In the April 1946 issue of the JOURNAL, the new wording is as follows:

> "**16-MM AND 8-MM MOTION PICTURES** (formerly Nontheatrical Equipment).—To make recommendations and prepare specifications for 16-mm and 8-mm cameras, 16-mm sound recorders and sound recording practices, 16-mm and 8-mm printers and other film laboratory equipment and practices, 16-mm and 8-mm projectors, splicing machines, screen dimensions and placement, loudspeaker output and placement, preview or theater arrangements, test films, and the like, which will improve the quality cf 16-mm and 8-mm motion pictures."

Our Committee now has 36 members, which means that it has been enlarged considerably. It has a definite job to do; one that

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* Presented May 10, 1946, at the Technical Conference in New York.

** Chairman.

should be completed as soon as possible. In 1941, the previous Committee issued a report entitled "Recommended Procedure and Equipment Specifications for Educational 16-Mm Projection." It was prepared for the Committee on Scientific Aids to Learning, of the National Research Council. There has been so much interest in the report that the supply of several thousand reprints has been depleted, and it was necessary to print a new issue. But there is another reason for revising the recommendations. There has been considerable progress since then, perhaps not so much in the equipment as in our appreciation of the more important aspects of the problem, accentuated by the requirements of the Armed Forces. In 1944 and 1945 a great deal of thought and effort was expended on American War Standards, through the Z52 Committee of the American Standards Association. The various subcommittees of Z52 were able to make use of the 1941 report of this Committee in preparing drafts for a number of the War Standards. With all the mental power that was available to Z52, it was inevitable that there should be advances in the understanding of the essential specifications and tests for 16-mm equipment. Those advances, in turn, made our 1941 report somewhat out of date. It is now our task to review the recommendations with the idea of using as much of the material as applies to classroom projection. Furthermore, we should make as much further progress as we can. This work is now under way.

Here is an illustration of the need for widening the scope of the report. Recently there has been a movement among those who are concerned with the future of the 16-mm educational program to acquaint the architects who are designing schools with the requirements for projection. There has been enough experience now, in the schools, to indicate that all the audio-visual aids should be co-ordinated and that the planning should start with the architect. There are so many factors, such as the shape of the room, provision for darkening the room, ventilation of darkened rooms, treatment of surfaces for good acoustics, and provision of electrical outlets, that it is essential for us to gather them together for the guidance of the architect. This is especially important in view of the large amount of school building that is now in the planning stage or in prospect.

Then there are other ways in which we can help the school authorities more than we have in the past. One of their problems is the training of volunteer student projectionists. It should be possible for us to help a great deal in this respect. We are fortunate in having, as

members of the Committee, men who have had experience in both administrative and field work in school projection, and we are planning to make the most of that experience. Moreover, we expect that they can tell us how to write and present our material in such a way that it will appeal to the educational authorities and be intelligible to them.

A tentative outline for the revised instructions has been prepared. Chapter headings include:

(*I*) Origin and Growth of Audio-Visual Aids to Education
(*II*) Architectural Design of Schools, Auditoriums, and Classrooms
(*III*) The Function of the Projector
(*IV*) Rearrangement of the Existing Classroom and Selection of the Screen
(*V*) Specifications for the Projector and the Sound Apparatus
(*VI*) Specifications for Arc Lamps
(*VII*) Duties of the Projectionist
(*VIII*) Care of the Film
(*IX*) Care of the Apparatus

A meeting of the Committee was held on November 2, 1945. At that time, the order of the outline was changed, and the material was classified into several groups.

Since then, previous specifications that bear on each subject listed in the outline have been combined in preparation for writing the revised copy. We hope that all the material on each subject can thus be kept together in the new issue.

When the time came to assign this material to the members for revision, it was apparent that we needed smaller working groups of four or five members each. For greater efficiency and speedier action, nine subcommittees are being appointed: Cinematography, Sound Recording, Test Films, Projection Practice, Projector Specifications (dealing with the projection of the picture), Projector Specifications (dealing with the reproduction of the sound), Laboratory Practice, Liaison and Advisory, and Editorial. These are temporary subcommittees, and there is no intention of making them obligatory for future chairmen of the parent Committee.

There has been some discussion about how the Committee can expand its activities so that its influence will be felt in other fields. There are organizations that can use our help if they know that they can turn to us. The Liaison and Advisory group will be useful in this work. For the immediate future, however, the school projection program is enough to require our undivided attention. The Editorial subcommittee will specify the form and style of the various sections of the new issue.

We wish to appeal to the members of the Society to give us all possible help for our preparation of better recommendations. Any technical information about the use of 16-mm sound projectors for the imparting of knowledge will be welcome. It will reach us safely if it is sent to Boyce Nemec, Engineering Secretary of the Society. We are especially interested in reaction to American War Standard *Z52.1-1944* issued by the American Standards Association and to the allied specifications included in that standard as appendices.

REPORT OF THE COMMITTEE ON STANDARDS*

F. T. BOWDITCH**

During recent months the Committee on Standards has become increasingly active. While the war was in progress, most standardization was done in the interests of the Armed Forces, under the auspices of special war committees of the American Standards Association on which many members of the Committee on Standards served. A great quantity of war standardization resulted which now requires consideration from a peacetime point of view. In addition, these new standards called attention to the need for modernization of older ones. First consideration of this matter was given by ASA Sectional Committee on Motion Pictures Z22, under the chairmanship of Clyde R. Keith.

In line with this procedure, Z22, in a meeting last October, reviewed all Motion Picture Standards then in existence, both the prewar Z22 Standards and the War Standards developed by Z52. Of the 53 standards so reviewed, 20 were reaffirmed in their existing form and six others have since been approved with minor editorial changes. These 26 have now been referred to the United Nations Standards Co-ordinating Committee for inclusion in their agenda. Of the remaining 27, three are under consideration by subcommittees of Z22, two have been referred to the Research Council of the Academy of

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* Presented May 10, 1946, at the Technical Conference in New York.

** Chairman.

Motion Picture Arts and Sciences, and 22 have been referred to the Committee on Standards of the SMPE.

This large number of standards was referred to our Committee primarily because each one of them represents a special technical problem. After several years of relative inactivity, we were thus suddenly faced with a task sufficient to occupy us for several years at the normal prewar pace of such work. Moreover, the ASA specifically requested prompt action on all these standards in order that as many as possible might be made ready for submission to the United Nations Committee before its first technical meeting.

In order to implement this work six subcommittees of the Committee on Standards have been formed, and each assigned a group of related standards for early consideration. These include subcommittees on

(*a*) *Projection Reels*, with three projects, under the chairmanship of D. F. Lyman;

(*b*) *Photographic Density and Sensitometry*, with two projects, under the chairmanship of D. R. White;

(*c*) *Cutting and Perforating Raw Stock*, with five projects, under the chairmanship of E. K. Carver;

(*d*) 16-*Mm and* 8-*Mm Camera and Projector Apertures*, with six projects, under the chairmanship of John A. Maurer;

(*e*) 16-*Mm and* 8-*Mm Projector Sprockets*, with four projects, under the chairmanship of Otto Sandvik; and

(*f*) *Film Splices*, with two projects, under the chairmanship of Wm. H. Offenhauser, Jr.

All of these subcommittees are actively at work and the revision of six of the 22 standards has now been agreed to in subcommittee and submitted to letter ballot of the parent Committee.

Another project of perennial interest to the Committee is that of the Glossary of Motion Picture Terms. After working on this task intermittently during the war years, the job, instead of diminishing toward completion, has actually grown larger as the result of the introduction of many new terms, while the manifestation of increased trade interest has further justified the early preparation of a glossary. This project has, therefore, been broken down into twelve parts according to field of interest. Nine of these are to be handled by present engineering committees, and three by special subcommittees of the Committee on Standards. It is hoped that in this way the task can be advanced to earlier completion with the publication of each section as it is finished rather than waiting for the entire job to be completed.

In 1941 an "SMPE Recommended Practice" with respect to the edge-numbering of 16-mm film was published in the JOURNAL for comment before consideration as an American Standard. A subcommittee of the Committee on Standards under the chairmanship of Lloyd Thompson was appointed about a year ago to review this situation. Mr. Thompson's subcommittee has recently recommended that this "Recommended Practice" be advanced to an American Standard, without change, that is with the specification of a 40-frame interval between numbers. The parent Committee at its meeting on May 8, 1946, approved this recommendation and authorized the first step toward American Standardization, that is, a letter ballot of the entire Committee on this Proposed Standard.

For many years a discussion has been active relative to the possible advantage of a 16-tooth intermittent projector sprocket larger in diameter than the 0.935-in. value now in use with 35-mm film. Laboratory tests have consistently indicated a much longer film life with a larger sprocket, but the practical application of such a sprocket had never been successfully accomplished. As long ago as 1930, American Standard *Z22.35* called for a diameter of 0.945 in. However, when this larger size was supplied to the trade in 1934, many complaints of noisy operation arose, attributed to sprocket wear by the film. Consequently, an expensive reversion to the 0.935-in. diameter followed with the result that *Z22.35* has never been a truly observed Standard.

In the recent war emergency the necessity for film conservation was responsible for a renewed consideration of this subject. A special Subcommittee on Intermittent Projector Sprockets for 35-Mm Film was formed under the chairmanship of Dr. E. K. Carver for this purpose. The committee had laboratory data indicating that at least double the film life could be obtained through the use of a larger sprocket. The problem was to determine how such a sprocket would stand up in service and if the initially apparent increase in film life persisted throughout sprocket life. After extensive tests with sprockets of several diameters in a number of theaters, the subcommittee found that the initial film saving does persist, and that sprocket wear is in no case faster and in many cases much slower than with the present 0.935-in. diameter sprocket. Increased projector noise, a possibility, originally the subject of much controversy, was simply nonexistent. The parent Committee has since approved by letter ballot the subcommittee's recommendation of an 0.943-in. diameter

sprocket and this recommendation had been in turn passed on to ASA Sectional Committee Z22.

Particularly in this last instance does the value of standardization become apparent. Potential saving in decreased film wear through adoption of this standard has more than justified the work of this committee, and we hope is typical of the engineering service which can now be supplied to the industry as a result of the recent central office expansion. A most important step in this direction is the acquisition of our full-time Engineering Secretary, Boyce Nemec, who can apply the needle when required to keep our projects on the move. Certainly we could not ask for better technical representation of the industry than that now provided on our present engineering committees. Under John Maurer's able direction, as Engineering Vice-President, and the application of Boyce's needle, we can expect real progress in the months to come.

REPORT OF THE COMMITTEE ON STUDIO LIGHTING*

C. W. HANDLEY**

Previous papers and reports have catalogued and described motion picture studio lighting equipment. The purpose of this report is to show the light output at various beam divergences of *some* of the popular types of equipment and to give an indication of the light levels used by *some* directors of photography. This information should give the reader a basis for general conclusions on the question of how much light is used.

Practically all of the lighting equipment used around the tops of sets on parallels and much of the floor lighting is accomplished by means of spotlamp units equipped with Fresnel-type lenses. These units are controlled as to spot diameter by moving the light source toward or away from the lens and are reduced in intensity at a given spot diameter by the use of frosted gelatin diffusers placed in front of

* Presented May 10, 1946, at the Technical Conference in New York.

** Chairman.

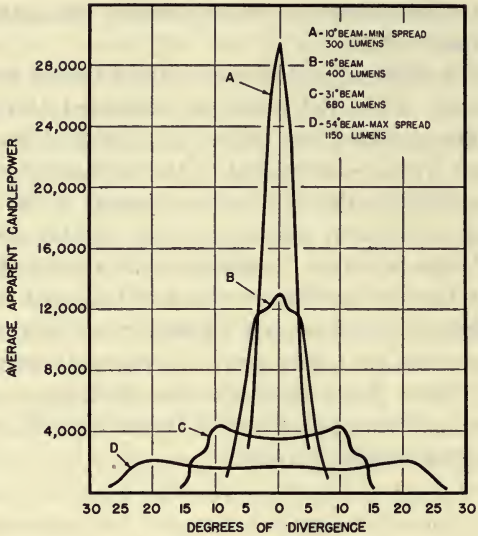

FIG. 1. Candlepower distribution from a Mole-Richardson "midget" incandescent spot type *404*, with a 200-w, *T-10* bulb d-c bayonet base lamp.

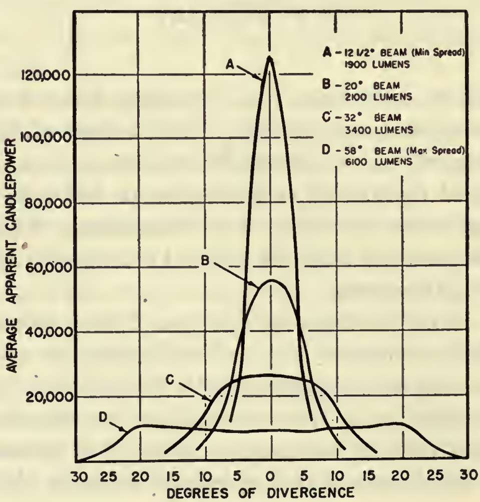

FIG. 2. Candlepower distribution from a Mole-Richardson "baby" solar spot, type *406* with a 750-w, *T-24* bulb medium bipost base *M.P.* type lamp.

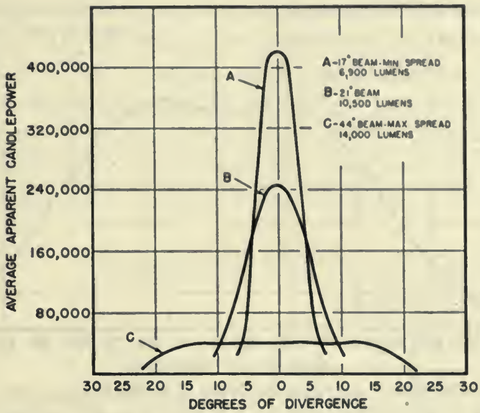

FIG. 3. Candlepower distribution from a Mole-Richardson "junior" solarspot type *410* with a 2000-w, *G-48* bulb mogul bipost base, *M.P.* type lamp.

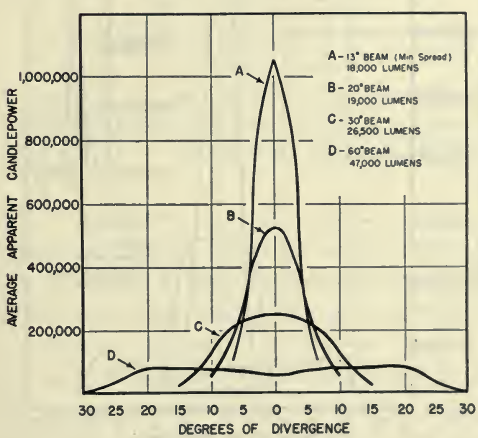

FIG. 4. Candlepower distribution from a Mole-Richardson "senior" solar spot type *414*, with a 5000-w, *G-64* bulb mogul bipost base lamp.

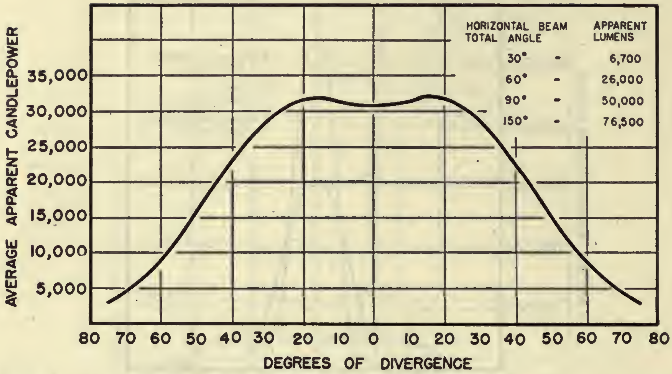

FIG. 5. Candlepower distribution from a Mole-Richardson "duarc" type *40* operating from a 120-v, d-c line, arc current 41 amp.

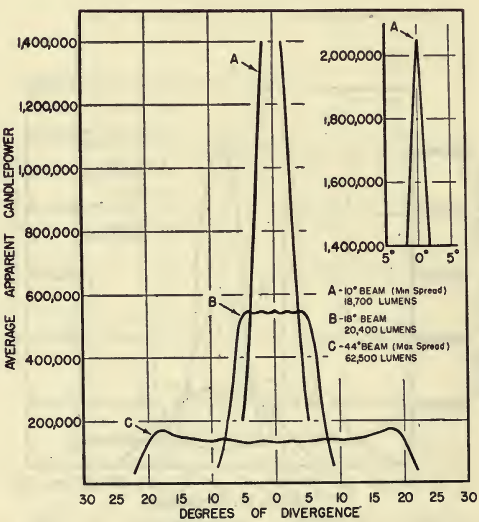

FIG. 6. Candlepower distribution from a Mole-Richardson high intensity arc spot, type *90* with 115-v, d-c arc operating at 110 amp, 60 arc v.

the lens. Figs. 1 to 6 show the average apparent candlepower and lumens output of a number of the spotlamp type units.

Fig. 7 shows the average apparent candlepower and lumens output at various angles of a carbon arc type broadside lamp which does not have adjustable beam spread and is used for general floodlighting.

For black-and-white cinematography, tungsten filament lamps are usually the main light sources, particularly on small sets. Carbon

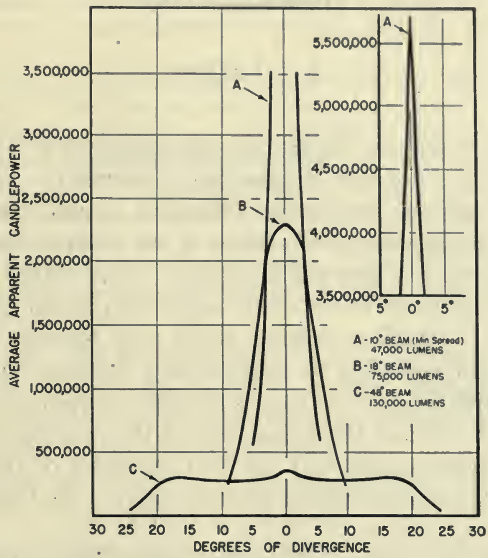

FIG. 7. Candlepower distribution from a Mole-Richardson high intensity arc spot, type *170* with 115-v, d-c arc operating at 140 to 145 amp, 60 to 70 arc v.

arc lamps are used for "streak lighting," shadow effects, and on larger sets where it is necessary to project light for considerable distances.

"Key-light" levels on black-and-white sets vary from 50 to as high as 400 ft-c.

Professional color cinematography is balanced to sunlight, therefore, carbon arc lamps are usually the main light sources. The flood-type carbon arc lamps are used without filters and the high-intensity rotating positive-carbon type spotlamps are equipped with light straw-colored gelatin filters known as "*Y-1*". Tungsten filament

lamps, fitted with blue filters for sunlight balance, are used on color where fill light is indicated on small sets and for softening the front illumination in closeups. The key-light levels in color cinematography vary from 250 to as high as 900 ft-c.

REPORT OF THE COMMITTEE ON TELEVISION PROJECTION PRACTICE*

P. J. LARSEN**

About a year ago this Committee was organized as a subcommittee of the Society's Theater Engineering Committee. At that time, its scope as outlined included specification, design, construction, installation, maintenance, and method of use of equipment for projection of television pictures in the theater. This entails recommendations for arrangement of television equipment in the theater or projection room, including definite plans and layouts necessary for such equipment including its location and electrical and mechanical association with the normal film projection equipment. This scope, therefore, also includes the dimensions of the projected picture, color spectrum of light source, and the characteristics of the reflective or translucent screen that may be used for viewing the theater television performances.

As noted in the above, the scope includes the specifications, design, construction, installation, maintenance, and method of use of equipment. This means that all matters dealing with theater television transmitters, relays from studio to transmitters and from city to city, receivers, projectors, and all the associated gear fall within the scope of the Committee.

The Committee is made up of members of the Society representing manufacturers of television equipment, theater circuits, motion picture producers and distributors, including newsreel companies, television broadcasting companies, architects, theater equipment dealers, and other interested members of the Society.

At its first meeting held on June 1, 1945, it was decided that four

* Presented May 10, 1946, at the Technical Conference in New York.

** Chairman.

Task Groups would be formed, each to make a study and furnish the Committee with information along the following lines:

(*1*) Task Group *A*—To furnish engineering information regarding existing and proposed theater television equipment with respect to size, weight, and shape of equipment, minimum and maximum size of projected image brightness attainable, type of system, line definition, type of screen and maximum viewing angle recommended, recommended location of equipment, *etc.*

(*2*) Task Group *B*—To furnish information regarding existing conditions in different types of motion picture theaters in this country with respect to physical condition and sizes of projection rooms, balconies, auditoriums, stages, viewing angles, *etc.*, for purposes of determining location of proposed theater television equipment.

(*3*) Task Group *C*—To furnish information in connection with picture quality, including resolution, color, gamma, contrast range, and screen characteristics, *etc.*, now available from monochrome and color film in order to determine the optimum equipment designed for theater television.

(*4*) Task Group *D*—To visualize what theater television is to be; namely, how theater television can be presented in theaters, its commercial aspects, the types of distribution systems required for inter- and intra-city, the problems of program pickup, storage of program material and scheduling distribution, the question as to the privacy of its programs and where reception and projection of broadcasting programs should be provided.

At the meeting held on September 26, 1945, preliminary reports were offered on Task Group *B* and *C*. At this same meeting there was some discussion led by D. E. Hyndman, President of the Society, with respect to the formation of Task Group *D*.

Formal reports were offered to the Committee at its meeting on April 4, 1946, by Task Groups *A*, *B*, and *C*. As a result of the discussion at this meeting, certain additional information is to be obtained by these Task Groups. However, it was agreed that further progress in the functions of the Committee now depend on the formation of Task Group *D* so that it might consider the information presented by the other Task Groups and make certain specific recommendations which would permit the Committee to proceed with its work. It appears that before much further progress can be made certain problems included in the scope of Task Group *D* would have to be agreed upon by the industry.

It is hoped that through co-operation with the Motion Picture Association, which represents the major motion picture film producers and distributors, and with the leading motion picture theater owner organizations, Task Group *D* can be formed in the near future and, without too much delay, contribute its assistance to the Committee and the Society.

MOTION PICTURES TOMORROW*

W. F. RODGERS**

As one who has given a business life of 35 years to the motion picture business, I feel grateful indeed for the opportunity to speak to the Society of Motion Picture Engineers. Individually and collectively you, as an organization, have made the most important contribution to the growth and stability of this great industry.

The technical or, as I would rather put it, the scientific and engineering progress you have made in sight and sound, in presentation, and projection, are the factors in a highly mechanized business that have made possible these wonders, for it remained for someone with the vision and the patience of a scientist and the foresight of an engineer to plan and nurse through experiments so important to the steady development of this business. Therefore, I salute you, gentlemen, for your ability and tenacity of foreseeing the coming of the scientific approach to this business.

That the days of the "hit-and-miss" approach to our problem are over must be evident. These are the days when no national merchant can afford to put a product on the market without first thorough, careful analysis to ascertain the market acceptance of that product, its probable source of sales, and which market is most likely to succeed.

As distributor, I, too, have seen a new approach—a business approach that first thinks out a problem and then analyzes the effects; and its success is, therefore, by no means accidental. Just as blueprints are necessary to an engineer, so does the new businessman's equipment require the facts, figures, charts and graphs.

Today motion pictures are receiving the greatest acceptance in the history of the business. That knowledge of making motion pictures on which you and others have burned so much midnight oil is paying its dividend. Mobilized of necessity during the war, the science of dis-

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* Presented May 6, 1946, at the opening luncheon, 59th Semiannual Technical Conference in New York.

** Vice-President in charge of Distribution, Loew's Incorporated, New York.

tribution, coupled with the science of presentation and the science of production, teamed well to do the greatest morale job in the history of the world.

In the tomorrow of the business that same scientific approach to our problems will continue to pay a dividend, for ours is a great responsibility if this war-torn world is to ever settle on the basis of a permanent peace. No medium, as so often it has been said before, can carry the message of the brotherhood of man as well as can motion pictures. And so, we see through our international departments the appearance of 16-mm projectors in the most remote localities throughout the world that all peoples may know that the world does not need bloodshed and starvation, but that the world they fought for is and can be a world of clean living, of peace and of plenty. That is our job and we here who make these pictures possible must feel the responsibility of doing the best job possible, that the by-product of our efforts will be the wider distribution of American-made motion pictures to the world.

To accomplish this we must face the future of our business ready to assist producers everywhere in their efforts to re-establish motion pictures of their own, and just as we will send them our product so must we be ready to accept whatever of their products are suitable to our audiences and throw into the discard once and for all that too-old bias against so-called "foreign" pictures. We could not maintain the high standard of production here if we could not expect to achieve world distribution over there. Any barriers that are erected because of our reluctance to give proper presentation to good pictures, regardless of their source, will only react on the quality of our own production. There is no need for a scientific approach to that one, it is just plain arithmetic.

In the tomorrow of the business, just as with the coming of sound we learned such new words as "acoustic," "photoelectric cells," "faders," *etc.*, so have we commenced to acknowledge the wisdom of research in the pursuit of scientific analysis of proposed titles, scientific analysis of market possibilities and proper approach, polling of communities to find out what mediums they react to the best—a constant search that old methods of "trial and error" be abandoned in favor of the facts on which an intelligent plan can be made. Advertising agencies are quietly investigating the proper type faces to which the public react best, how can this picture best be merchandised through radio, newspapers, word of mouth, magazines, and where are they the strongest.

We in the Sales Department are pouring over charts to see whether the public demand for a picture has reached the necessary point that will enable it to reach the greatest number of patrons, analyzing these reports that we may price our merchandise for the individual situation, all aimed to permit all types of theaters in all types of localities better to withstand the various types of competition which is bound to come once the world returns to its peacetime activities.

Ours, too, is a great responsibility that we encourage our theater owners to try to influence more people to appreciate the marvel of motion pictures as the greatest amusement value in the world. It is also our responsibility that this great product conceived in Hollywood through the use of all the latest authentic and mechanical methods for which you are responsible be given every aid that more and more of our public become motion picture conscious.

And so with you unceasingly continuing the work of the Society of Motion Picture Engineers, with Hollywood alert to pick the best in literature and transfer it into great productions through the science of their creative genius, with the science of advertising and market analysis available to us and the science of sales well past the formula of "I want and you'll give", and with the science of exhibition, one that is today occupying the attention of every thinking theater owner who knows full well that the physical appointments of his theater and science of public relations are vital to his success, it seems to me we lack just one science; at least there is one that has not been given the attention it must receive if, in the new scientific world of tomorrow, motion pictures are to be ready to march side by side with the other great businesses of the world.

It's the science of industry team play. I am sure during this last bitter struggle there must have been many disagreements over policy, many disappointments, yet all interested faced the enemy as a team, one part making up for the weakness of the other toward their mutual self-preservation and eventual victory.

We, too, will always have our internal differences, regrettable as they may be, but the importance of a unified pride in our business, the vital necessity of an appreciation that the other fellow, too, has problems, and an appreciation of his efforts toward the success of the business as a whole, that science of team play must be redeveloped if we are to be able to make the progress ahead that we can make. As I said in the beginning, I have been identified with this business for more than 35 proud years, and anytime I hear any element of

the business carelessly referred to, or anytime it is unfairly attacked and the industry does not rise in righteous indignation to defend an industry that has done so much, not only for all of us, but for the world at large, I shudder at our thoughtlessness. The science of team play—of appreciating the other fellow's contribution to the business, of an all-out one-for-all love of the business and a solemn resolve to make our individual contribution to a better public appreciation of our business—that, gentlemen, is a must for tomorrow; that, gentlemen, is a science that does need developing and will spell, in the final analysis, achievement.

We who are in the business are looked on as experts on motion pictures, our opinions are sought, people like to talk to us about movies. Let us then, therefore, in the tomorrow of peace highly resolve that our individual part in its success over and beyond our business contributions shall be to say and say again, "It's a great, fine business, with a majority of great, fine people in it doing, on the whole, a great, fine job of making motion pictures the world's greatest entertainment value."

PRESENTATION OF SCROLL TO THOMAS ARMAT*

DONALD E. HYNDMAN**

The date of April 23, 1946, marked 50 years since Thomas Armat gave the first exhibition in a theater of motion pictures as we know them today. The exhibition was given in Koster & Bial's Music Hall in New York City where Mr. Armat personally operated the projector on this first historic night marking the beginning of what we know today as one of the seven major industries of the United States.

The projector he used was designed by him and embodied a new feature of relatively long periods of rest and illumination of each successive picture on the film. This projector was then known as the Vitascope.

Approximately ten years ago, Mr. Armat was made an Honorary Member of our Society and, tonight, we are honoring him with a citation scroll of his pioneering work in our motion picture industry. It is appropriate to report for history on this most historic occasion that, when he brought the motion picture to the screen, he made it strictly a silk-hat occasion.

The fact is that Mr. Armat, then a blithe figure of a young business man of thirty and launched on a successful career in Washington business and with all the tradition of a F.F.V. (First Families of Virginia) behind him, was tremendously impressed with an invitation to bring his Vitascope to New Jersey and demonstrate it before the great Thomas A. Edison. In the 1890's in Washington all big events called for formal dress.

Mr. Armat arrived at West Orange, New Jersey, one afternoon in a silk hat and frock coat and with the Vitascope in a trunk. He was a bit overwhelmed when he was invited into a smoky, dusty barn of a foundry with a group of shirt-sleeved laboratory assistants and overalled mechanics there to help Mr. Edison look at the new projector.

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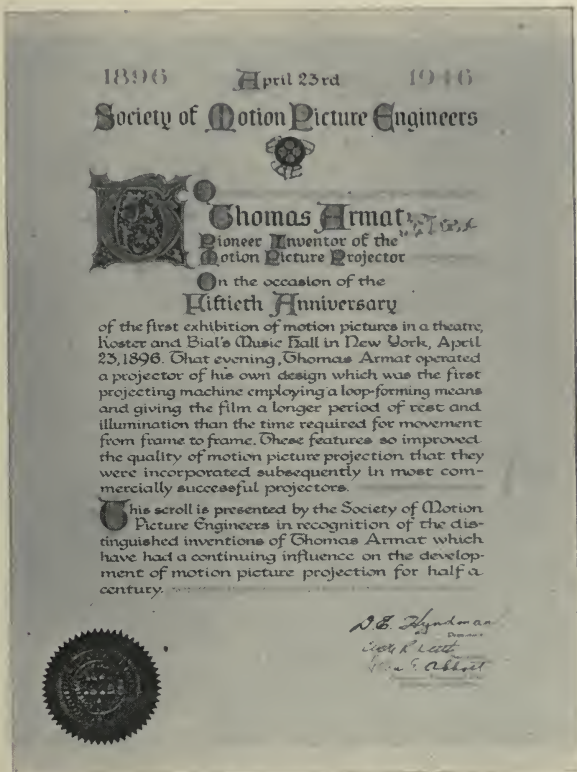
* Presented May 8, 1946, at the dinner-dance, 59th Semiannual Technical Conference in New York.

** President, SMPE.

Doubtless Mr. Edison and the hired hands were impressed with Mr. Armat's silk hat, too. Anyway, we can be assured that projection came to the movies in style. Mr. Armat rates special honors, then, not only for his contribution to the theater screen but also for being the first genuine silk-hat engineer of our industry.


1896 April 23rd 1946

Society of Motion Picture Engineers

To Thomas Armat

Pioneer Inventor of the Motion Picture Projector

On the occasion of the Fiftieth Anniversary

of the first exhibition of motion pictures in a theatre, Koster and Bial's Music Hall in New York, April 23, 1896. That evening, Thomas Armat operated a projector of his own design which was the first projecting machine employing a loop-forming means and giving the film a longer period of rest and illumination than the time required for movement from frame to frame. These features so improved the quality of motion picture projection that they were incorporated subsequently in most commercially successful projectors.

This scroll is presented by the Society of Motion Picture Engineers in recognition of the distinguished inventions of Thomas Armat which have had a continuing influence on the development of motion picture projection for half a century.

FIG. 1. Scroll presented to Thomas Armat.

On behalf of our Society, I now take great pleasure in presenting to Brooke Armat, son of Thomas Armat, this anniversary scroll which reads as follows:

"To Thomas Armat, pioneer inventor of the motion picture projector on the occasion of the Fiftieth Anniversary of the first exhibition of motion pictures in a theater, Koster and Bial's Music Hall in New York, April 23, 1896. That evening, Thomas Armat operated a

projector of his own design which was the first projecting machine employing a loop-forming means and giving the film a longer period of rest and illumination than the time required for movement from frame to frame. These features so improved the quality of motion picture projection that they were incorporated subsequently in most commercially successful projectors.

FIG. 2. THOMAS ARMAT.

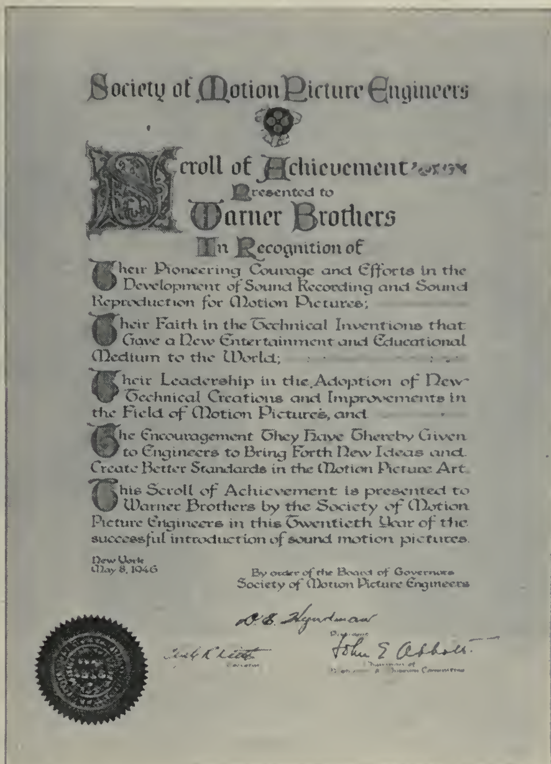
"This scroll is presented by the Society of Motion Picture Engineers in recognition of the distinguished inventions of Thomas Armat which have had a continuing influence on the development of motion picture projection for half a century."

[Mr. Armat accepted the illuminated scroll on behalf of his father, who was unable to be present, with deep appreciation and gratitude.]

PRESENTATION OF SCROLL TO WARNER BROTHERS

[President Hyndman continued:]

We have already been privileged tonight to honor a distinguished motion picture pioneer, Thomas Armat—and now it gives me equal pleasure to announce another citation by our Society.



Society of Motion Picture Engineers

Scroll of Achievement
Presented to
Warner Brothers
In Recognition of

Their Pioneering Courage and Efforts in the Development of Sound Recording and Sound Reproduction for Motion Pictures;

Their Faith in the Technical Inventions that Gave a New Entertainment and Educational Medium to the World;

Their Leadership in the Adoption of New Technical Creations and Improvements in the Field of Motion Pictures, and

The Encouragement They Have Thereby Given to Engineers to Bring Forth New Ideas and Create Better Standards in the Motion Picture Art.

This Scroll of Achievement is presented to Warner Brothers by the Society of Motion Picture Engineers in this Twentieth Year of the successful introduction of sound motion pictures.

New York
May 8, 1946

By order of the Board of Governors
Society of Motion Picture Engineers

FIG. 3. Scroll presented to Warner Brothers.

After *motion* pictures, there came *sound* pictures. But they did not just come. They had to be visualized, engineered, developed, and made into a practical, commercial article.

Thomas A. Edison and Dr. Lee de Forest were among the first to visualize this dream and to demonstrate its possibilities.

Many other inventors, technicians, and engineers also worked on the idea—but except for Edison, de Forest, Fox-Case, the Bell Laboratories, Western Electric, Eastman, RCA, General Electric, du Pont, and a few others, most of them eventually gave it up as impractical.

Nearly everybody in the amusement business, too, after attending dozens of experiments and demonstrations, became fed up with the idea of talking pictures and declared that it could never be turned into a commercial success.

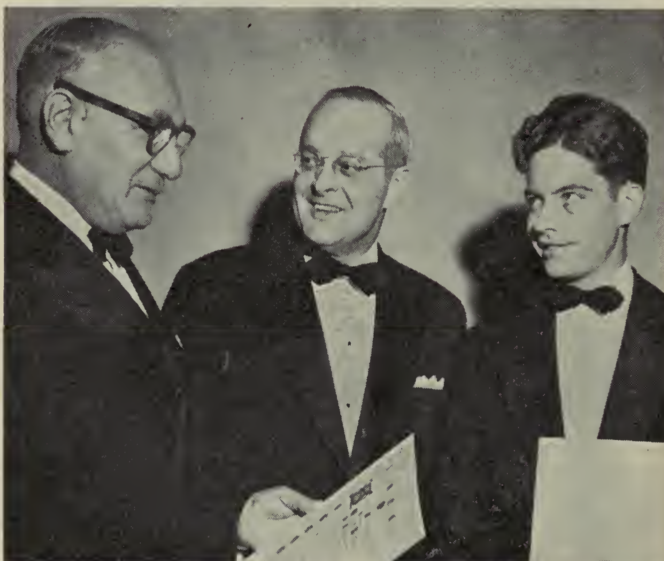


FIG. 4. Left to right, MAJOR ALBERT WARNER, PRESIDENT HYNDMAN, AND BROOKE ARMAT.

Then along came four young men who had more faith, more determination and more perseverance. Those four boys were Harry, Jack, Albert, and the late Sam Warner.

They not only defied the skeptics who scoffed at the idea of talking motion pictures, but they gambled everything they had on the new invention—and it's no secret to many of you that in the year just before they presented their first synchronized picture, *Don Juan*, on August 6, 1926, and in the year that followed, when they brought out *The Jazz Singer* with the first line of dialogue ever spoken from the

screen, the Warner finances were so low that employees often had to be asked to hold off cashing their weekly pay checks for a few days after receiving them.

But the Warners saw it through, and you know the rest.

We are honored to have with us here tonight one of those four courageous brothers, Major Albert Warner—and on behalf of our Society, I now take great pleasure in presenting to Major Warner this Scroll of Achievement, which reads as follows:

"In recognition of their pioneering courage and efforts in the development of sound recording and sound reproduction for motion pictures; their faith in the technical inventions that gave a new entertainment and educational medium to the world; their leadership in the adoption of new technical creations and improvements in the field of motion pictures; and the encouragement they have thereby given to engineers to bring forth new ideas and create better standards in the motion picture art; this Scroll of Achievement is presented to Warner Brothers by the Society of Motion Picture Engineers in this Twentieth Year of the successful introduction of sound motion pictures.

"By order of the Board of Governors, Society of Motion Picture Engineers."

[Accepting the scroll on behalf of his brothers and himself, Major Warner acknowledged the honor with the following words:]

Mr. President, Honored Guests, Ladies and Gentlemen: I am very deeply honored to accept this scroll on behalf of my brothers and myself.

It is true that the Warner Brothers brought sound and talking pictures out of the laboratory and gave them to the world as a new form of entertainment. But a large measure of the credit for that development goes to you engineers.

The success of talking pictures was a victory for engineering genius as well as an achievement of the motion picture studio. You men perfected the machine. We supplied the showmanship. The importance of the engineer in the field of motion picture development has never been fully appreciated. Few persons know how much we owe you men, not only for what you did in the field of sound, but also in color, in working out equipment standards for theaters and studios, and in the new work you are constantly doing to improve

our sound equipment so that pictures can be produced more efficiently and shown to the best advantage.

This year not only marks the twentieth anniversary of talking pictures, but it is also the fiftieth anniversary of motion pictures as commercial entertainment, and I should like to take this opportunity to pay my respects to Thomas Armat, the "father of the projector," whom you have just honored here tonight. If Armat had not followed through with his engineering skill and perfected the device that made it possible to project pictures on a big screen, there would have been no motion pictures—and no talking pictures—at least, not until some other engineer had the perseverance to solve the technical problems involved.

Giving talking pictures to the world was not a one-man or one-company proposition. Many talented men, many members of the Society of Motion Picture Engineers who are here tonight, and several big companies like Western Electric, Bell Telephone, Eastman Kodak, Edison, RCA Victor, and others, played a big part. So our twentieth sound anniversary, and this Scroll of Achievement, is a tribute to all of them as well as to Warner Brothers. I only regret that my brother Sam, who worked hardest to overcome the early difficulties in the making of talking pictures, is not here tonight to share in this honor.

I do not know what will be the next great contribution of the engineers to the entertainment industry—whether it will be third dimension, or television, or new refinements in the equipment we now have, or whatever it may turn out to be. But I know that your work is not finished. You engineers are just as much a part of our industry as the actors, writers, directors, producers, film salesmen and exhibitors.

New horizons are in sight for motion pictures—in the fields of education, culture, human relations, business—and above all, in the great work of promoting American ideals of democracy, world unity and peace. Your work can help to rid civilization of demagogues who preach the doctrine of "divide and conquer" that destroyed a large part of the world. We do not want agitators of that kind to gain a foothold here and destroy this great land of liberty.

Right now, if we are not careful, we will lose the peace we fought so hard to win. So it is up to all of us to keep working together to assure a peaceful world. We must not leave the way open for another war by settling for a soft peace.

To attain these ends for humanity, we need your talents and your efforts more than ever. The screen cannot march forward to new and higher achievements unless it marches hand-in-hand with the men who work out the technical problems—the motion picture engineers.

A SIMPLIFIED RECORDING TRANSMISSION SYSTEM*

F. L. HOPPER AND R. C. MOODY**

Summary.—*This paper describes a recording transmision system in a single, compact, lightweight unit, capable of excellent performance together with reliable and simple operation.*

There are many applications for a simplified recording transmission system in both the domestic and foreign fields. Such a system would supply all the necessary equipment to operate from a microphone and into a sound recording modulator. A minimum number of operating controls would be provided, in order that the operation of the system be as simple as possible. Reliability, with a high standard of performance, is another of the principal requirements. The system should operate from a variety of power sources and should be capable of operating several types of light valve modulators. Applications include: Use of the system with newsreel cameras, with a small recorder for superportable field use where a double film system is required, or for use with double film systems where a relatively simple and inexpensive equipment is required. It is the purpose of this paper to discuss such a transmission system.

A survey of the fields to which this unit might be applied indicated the following requirements:

(*1*) The equipment should be light, compact, sturdy, and all parts should be easily accessible.

(*2*) Maximum reliability of operation is essential, hence the circuits should be simple, a minimum of controls should be employed, and components and wiring should be moisture resistant. Each component should justify its inclusion in order that the system have minimum components.

(*3*) Power consumption should be a minimum so that the unit may be operated from batteries, or if alternating current is generally available, from a-c operated rectifiers.

(*4*) Performance should be adequate for the types of recording service for which the equipment is proposed. In this respect, the system provides considerable improvement compared over those developed in the past.[1,2]

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* Presented Oct. 15, 1945, at the Technical Conference in New York.

** Electrical Research Products Division, Western Electric Company, Los Angeles, Calif.

(5) Ease of service of the equipment in the field when away from permanent test facilities.

The transmission equipment is housed in a rectangular duralumi-num case 15 in. long, 11 in. high, and 7 in. wide, and weighs 25 lb. The chassis, which includes the top panel, carrying operating controls, is easily removed from the case, even with all connecting cables attached. The vertical portion of the chassis is employed to support the transformers, retards, and vacuum tubes, single-side mounted. Terminal cards, carried across the back of the vertical chassis, are

FIG. 1. *RA-1253* amplifier.

employed to support resistor and condenser components. All components are designated, and operating voltages which appear across such items as plate and cathode resistors are indicated in order to facilitate rapid checking or test. These cards are easily removed, giving access to equipment terminals underneath. This method of assembly permits of simple direct wiring and minimum use of cable forms, resulting in reduced wiring costs. Fig. 1 shows the equipment in its case, and Fig. 2 the chassis only.

Reference to Fig. 3, which is a schematic, will indicate the various electrical components comprising the system. The circuits nomi-

nally divide into two parts, the main transmission system which supplies program material to the modulator, and the noise reduction.

Facilities associated with the amplifier are:

(*1*) Two position mixer,
(*2*) Variable dialogue equalization,
(*3*) Interstage gain control,
(*4*) Peak limiting,
(*5*) Volume indicator,
(*6*) Headset monitoring,
(*7*) Modulator equalizer,
(*8*) Modulator "off-on" switch,
(*9*) Plate and heater "off-on" switches.

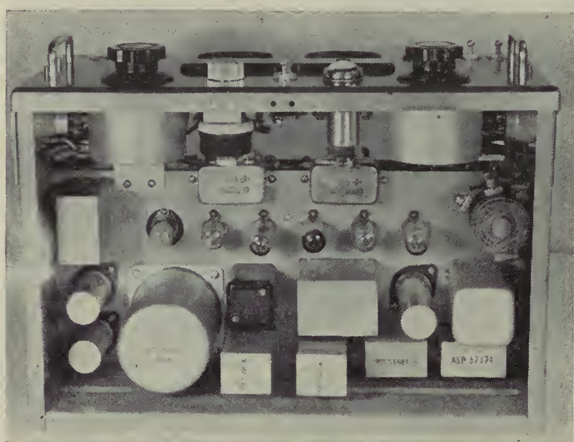

FIG. 2. *RA-1253* amplifier chassis.

Facilities associated with the noise reduction are:

(*1*) Margin control (internal),
(*2*) Bias control (internal),
(*3*) Bias "off-on" switch.

In addition to these controls, certain others are provided which may or may not be used depending upon whether the film recorder is of the single or double film type. These facilities generally are concerned with the recorder lamp and its associated controls.

The amplifier consists of 3 pentode connected stages with feedback around the last 2 stages. Adequate feedback is used to insure a wide

margin of stability and a high degree of damping. With all feedback removed the amplifier is reasonably stable and has 125-db gain. The application of feedback, which reduces the gain to 95 db, contributes its total effect to increased stability and damping.

Plate current drain was reduced as much as was consistent with the desired over-all performance from the viewpoint of harmonic distortion. The plate consumption of the 3-stage amplifier is 11 milliamperes at 180 v. Examination of the distortion-frequency characteristic, curve B of Fig. 4, shows one per cent distortion or less at all fre-

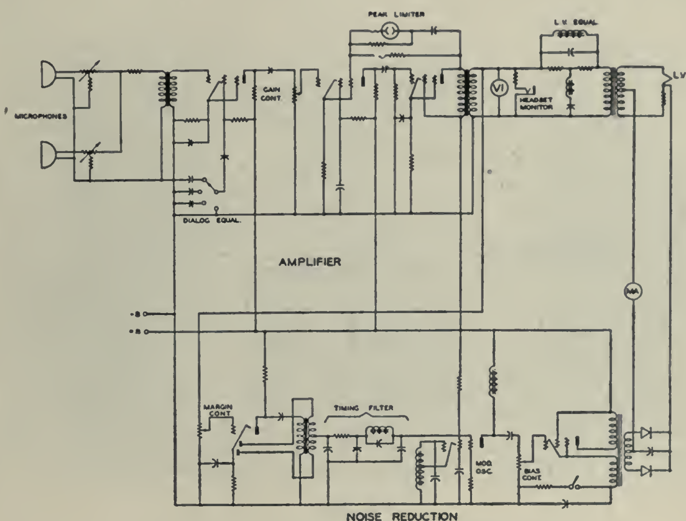

FIG. 3. *RA-1253* amplifier schematic.

quencies from 50 to 7500 cycles at an output of +12 dbm, which is a nominal value for the modulator overload.

The maximum output amplitude is limited at +18 dbm to protect the light valve from accidental overload which might cause damage. The limiting point occurs 6 db above nominal modulator overload so that the distortion generated by the peak chopping action is not observed. This limiting action is accomplished by a cold cathode type of voltage regulator tube placed in shunt with the feedback resistor. When the peak signal voltage exceeds the ignition voltage of this tube the amplitude is effectively limited by a corresponding increase in the amount of feedback. So that the blocking condenser associ-

ated with the cold cathode tube will not accumulate a charge, a high resistance is placed across the tube. Limiting is equally effective on both halves of the wave. The cold cathode regulator tube may be visually observed by the operator through a bull's eye on the front panel. Action of the tube, *i. e.*, peak chopping, is indicated by the visual glow discharge of the tube when the output of the amplifier is sufficient to cause it to operate. Curve *A* of Fig. 4 shows the amplifier distortion at the threshold of amplitude limiting.

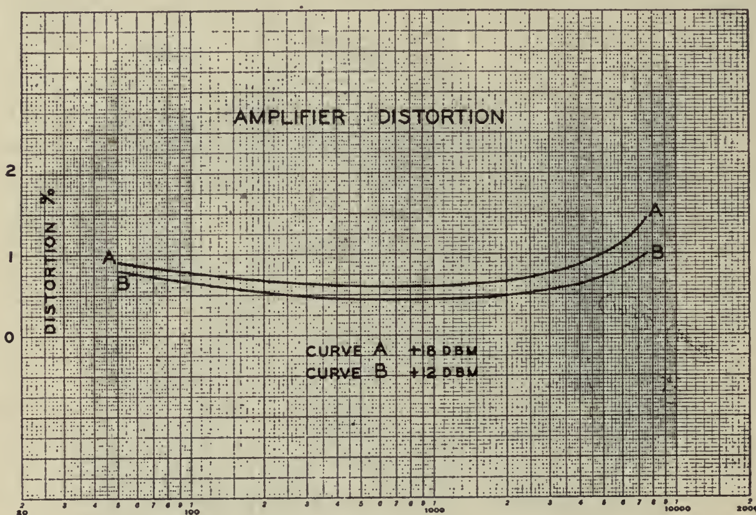

FIG. 4.

Two microphone input positions are provided. By means of an adaptor either of the microphone circuits may be connected to a transmission line or bridging bus. Low level mixing is employed in the interests of simplified design and reduction in size, weight, and number of components. The mixer inputs are designed to operate from a nominal 30-ohm impedance, thus accommodating most types of microphones. A switch-type interstage gain control for large gain adjustments is provided on the front panel. Maximum gains of 95, 80, and 65 db are available.

Dialogue equalization is obtained by screen grid degeneration. A 4-position switch placed on the front panel gives zero-, 4-, 7-, and 10-db equalization at 100 cycles. Degenerative equalization does not

impair the circuit stability and improves it at low frequencies. The gain-frequency characteristics of the amplifier and the 3 steps of dialogue equalization are shown in Fig. 5.

Fig. 5 also shows a modulator equalizer characteristic which compensates for a particular modulator resonance characteristic. The equalizer is the constant resistance type so that the amplifier works into a constant load at all frequencies. By the same token, the modulator is supplied from a constant resistance generator, hence no isolating pads are required, and the volume indicator may be bridged across either end of the circuit with the assurance that correct read-

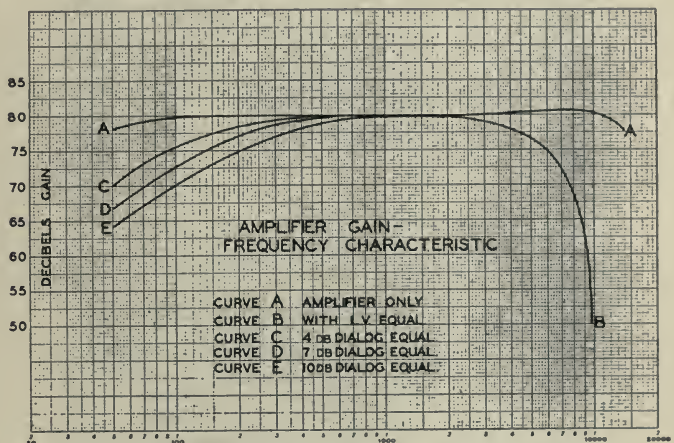

FIG. 5.

ings will be obtained at all frequencies. The equalizer has a frequency response characteristic which is complementary to that of the light valve. The combination of equalizer and light valve is therefore uniform with frequency, and material improvement in transient performance of the light valve is realized.

Headset monitoring is provided by means of a high impedance bridge across the output of the amplifier. Either the *705*-type moving coil headset, or the *713*-type molded earpiece receiver may be accommodated.

The noise-reduction circuit is of the carrier type and has been greatly improved from a standpoint of simplicity of adjustment and operation.

The modulating voltage is obtained from a triode-diode amplifier-rectifier and a timing filter. The grid of this tube is supplied from a margin potentiometer which is bridged across the amplifier output. The plate circuit of the tube supplies a transformer which in turn provides full wave connections for the diode. Bias threshold is obtained by adjustment of the cathode resistor. Fig. 6 shows three possible

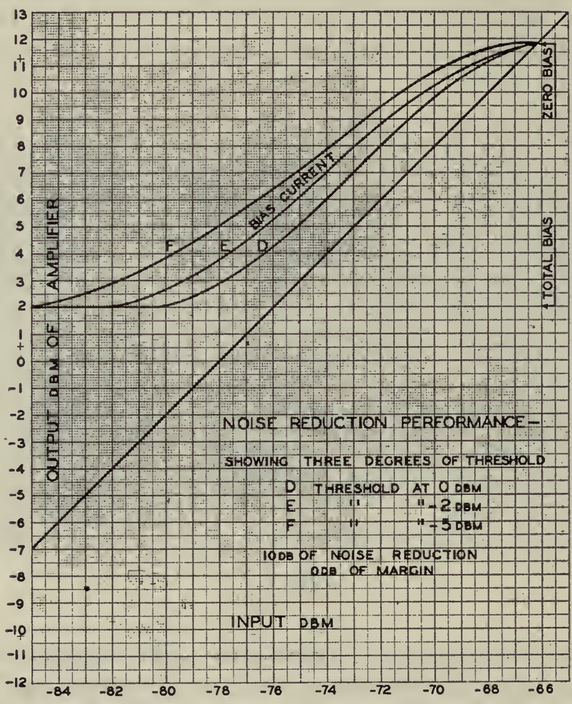

Fig. 6.

threshold adjustments. Fig. 7 shows three possible margin adjustments. While it is apparent that a wide variety of threshold and margin conditions are available, it is expected that proper adjustments will be selected for any one type of modulator and film. Such adjustments do not appear upon the control panel, and must be made internally. The operation of the system is sufficiently stable so that these adjustments need be made only infrequently.

The timing filter shown in the schematic diagram, Fig. 3, is used for standard track recording. Push-pull filters, or filters having different attack and release times, may of course be substituted.

A single suppressor gird pentode tube is used as the oscillator and modulator. The total current consumption of this tube is less than one milliampere. The oscillator is of the conventional Hartley type

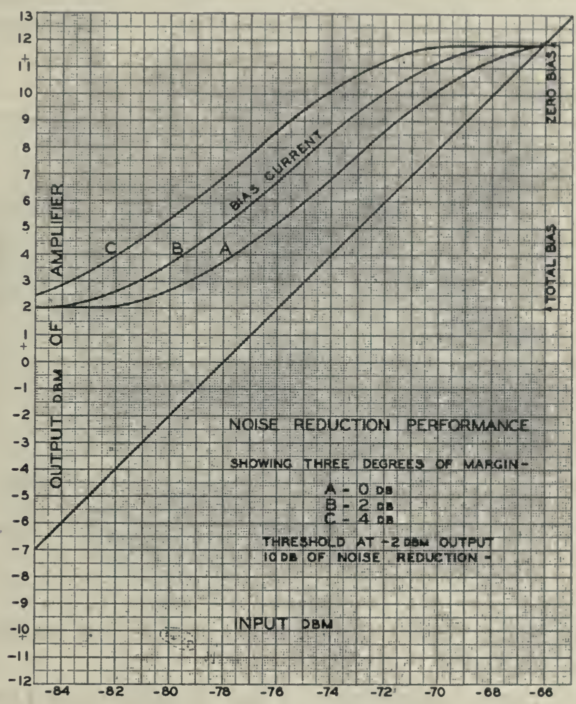

FIG. 7.

with a center tapped coil. This makes the feedback factor β positive and unity. The consequent mismatch between tube and tank circuit improves the frequency stability. There is no need for oscillator kc tuning as the tank coil and condenser are selected to 30 ± 2 kc tolerance in manufacture. The oscillator output is sufficiently stable so that there is no necessity for adjustment over long periods of time.

Modulation is applied to the third grid of the suppressor grid pentode. No critical bias conditions are required for operation as a modulator. Only 2 v peak are required for complete carrier cancellation.

The output of the oscillator-modulator is of the order of 12 v maximum. This is applied to a potentiometer. The potentiometer slider is connected to a pentode carrier amplifier. The carrier output transformer is uniform ±10 per cent from 20 to 40 kc so that any oscillator drift from a 30-kc mean frequency does not affect the output. Feedback is applied from a third winding on the transformer in series with the output pentode cathode. The effect of this feedback is two-fold, the linearity of the copper-oxide rectifier is greatly improved and the tube constants have little effect on the output current. The output of the copper-oxide rectifier is filtered with a 500 mfd condenser. This noise-reduction circuit is capable of supplying 300 milliamperes

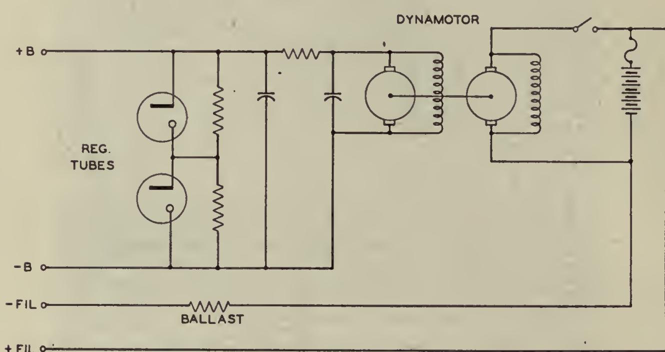

Fig. 8. *RA-1254* power supply schematic.

to a 1.5-ohm load. Total current drain of the noise reduction is 11 milliamperes at 180 v.

The total power consumption of the amplifier-noise reduction is one ampere at 6 v and 22 milliamperes at 180 v.

Power for the system may be obtained from a-c operated rectifiers when it is associated with a film recorder which utilizes such power. For use with newsreel systems where the primary power source is a 12-v storage battery, a dynamotor is provided to supply plate potential. Thus, the battery supplies power for the camera motor, recorder lamp, amplifier tube heaters, and the dynamotor. The dynamotor is small, weighs less than 3 lb and requires only 18 w for its operation. Fig. 8 shows power supply schematic and indicates that 180-v regulation is secured through the use of two regulator tubes. These draw only 8 milliamperes on the average. In addition, a bal-

last lamp is used in series with the vacuum tube heaters, insuring proper operating voltage to the tubes. With these regulating provisions, system performance is consistent over the useful range of the storage battery voltage from full charge to discharge. Fig. 9 is a photograph of this particular power supply unit.

Two 10-ft, 6-conductor cables are used between the amplifier-noise reduction unit and the battery power supply. An additional 6-conductor cable is connected from the power supply to the modulator on the camera.

FIG. 9. *RA-1254* power supply.

The described system affords in a single compact, lightweight unit, a transmission system capable of excellent performance together with reliable and simple operation.

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[1] HOPPER, F. L., MANDERFELD, E. C., AND SCOVILLE, R. R.: "A New High-Quality Portable Film Recording System," *J. Soc. Mot. Pict. Eng.*, **XXVIII**, 2 (Feb. 1937), p. 191.

[2] HOPPER, F. L., MANDERFELD, E. C., AND SCOVILLE, R. R.: "A Lightweight Sound Recording System," *J. Soc. Mot. Pict. Eng.*, **XXXIII**, 4 (Oct. 1939), p. 449.

THE PHOTOMETRIC CALIBRATION OF LENS APERTURES*

ALLEN E. MURRAY**

Summary.—*An absolute and physically sound method developed at Bausch & Lomb is described for the photometric calibration of lens apertures.*

Essentially the method consists in comparing the total flux from a depolished opal glass aperture with the flux through a given lens at a definite stop opening when focused on the opal glass aperture. An integrating sphere is used to collect the flux in the two cases and readings are made proportional to the flux with two matched barrier layer photocells. The theoretical development and some numerical results are given.

It is well known that the square of the ratio of the diameter of the entrance pupil to the equivalent focal length of a lens is an inadequate characterization of its transmission. For one thing, the individual surfaces reflect a certain amount of light, which is thus lost to the image, though some may be passed eventually to the image plane as "flare." In addition, the glass elements absorb a certain amount and the natural vignetting takes its toll so that the total transmission over a finite image area is relatively less than over a small area about the lens axis. Further, the unavoidable manufacturing tolerances conspire to make the marked $f/$values only approximately representative of the relative amount of light transmitted to the image. In some instances, the latter cause alone may lead to about 10 per cent error in $f/$number[1] even in closely controlled lens manufacture.

These problems have been appreciated for some time by the cinematographers, who must exercise close control over exposure to insure the desired photographic quality. Numerous schemes[2–4,10] have been proposed in the past all looking to establishing a method of measuring the transmission of an objective over its range of $f/$values, thus to the setting up of a series of effective transmission values more closely correlated with the exposures required to produce a given density than are the geometrical $f/$numbers. These schemes are all arbitrary in that the proposal is made either to measure the trans-

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* Presented May 10, 1946, at the Technical Conference in New York.

** Scientific Bureau, Bausch & Lomb Optical Co., Rochester, N. Y.

mission of the test lens against the transmission of a geometrically defined aperture, or against a lens chosen as standard.

Both of these proposals have disadvantages, though the former, by techniques herein indicated, could be made to provide a satisfactory standard method of photometric calibration. The objections to the latter method are so obvious they will not be noted beyond indicating that the method is valid essentially for only one laboratory.

In the search for a method which would be universally valid, and which could be used in any laboratory desiring to build the equipment and which would yield significant results without the necessity of standardization, the present physically sound, absolute method of photometric lens calibration was developed at Bausch & Lomb. This method does not depend on arbitrary apertures or lenses, and yields immediately either the effective *f*/number or, assuming the *f*/number is marked, the more elegant transmittance[5] which is known[6] to be a function of the geometrical *f*/number.

Essentially, the method consists in comparing the total flux transmitted by a lens at a given stop with the total emitted by a Lambertian aperture. The ratio of these two gives a quantity proportional to the transmittance of the lens and inversely proportional to the square of twice the *f*/number.

In practice, a depolished opal glass aperture, which is masked to the standard 35-mm sound film aperture dimensions, is placed flush with the wall of the integrating sphere. The total flux from the film aperture is thereby measured. The second step consists in introducing between the aperture and the sphere opening the lens under test, which is focused on the aperture by autocollimation. The flux through the objective at the various stops is collected by the integrating sphere, thus yielding in conjunction with the previous measurement, the desired primary data.

Theoretical.—The total flux emitted by a perfectly diffusing source of area A and brightness B is[7] $F = \pi BA$. Now, if the area is small, and we introduce before it at a distance r a parallel circular area of radius h, the solid angle subtended by the second area at the position of the first is simply $(h/r)^2$ and the total flux passing through the second area is given by the amount of the flux emitted and this solid angle

$$F = \pi BA(h/r)^2.$$

(This development is tantamount to assuming that all distances are large enough that the inverse square law is sufficiently accurate.

However, the corrections are not difficult to derive[8] and can be shown to amount at most to a fraction of one per cent with magnitudes of present concern.)

If a lens is now focused on the film aperture of brightness B and area A, h in the previous equation becomes the radius of the exit pupil and r the equivalent focal length of the lens, assuming that the pupils are very close to the principal planes. Since the exit and entrance pupils are conjugate to one another, the radius of the latter can be substituted for the former, and the flux through the lens becomes

$$F = \pi BA\left(\frac{h}{f}\right)^2 = \pi BA\left(\frac{d}{2f}\right)^2$$

or, upon introducing the f/number defined as the ratio of the focal length to the diameter of the entrance pupil, and introducing also the transmittance κ, the flux through the lens becomes

$$F = \pi BA \frac{\kappa}{(2f_n)^2} \qquad f_n \equiv \frac{f}{d}.$$

Or, in terms of the total flux emitted by the film aperture

$$F_0 = \pi BA$$

the flux transmitted by a lens at a given stop is

$$F = \frac{\kappa}{(2f_n)^2} F_0.$$

It is clear that the ratio F/F_0 is a measure of the photometric efficacy of the lens, and may be used to define the effective stops ("photometric f/numbers," or, as suggested by Berlant,[4] "t/numbers"). In accordance with the traditional relationships defining the geometrical f/numbers, the photometric f/numbers are defined in the following manner:

$$\text{(photometric } f\text{/number)} \equiv f_n^* = \frac{1}{2}\sqrt{\frac{F_0}{F}}$$

and thus the relationship between the "photometric f/number" and the traditional geometrical f/number becomes

$$f_n^* = \frac{f_n}{\sqrt{\kappa}}.$$

To avoid all questions of possible circuit nonlinearity and photocell response drift, a balanced 2-cell circuit was chosen whereby to measure these fluxes. The lamp house is provided at the rear with a

window of depolished opal glass similar to that used at the film aperture on the latter of which the lens is focused, the flux in the integrating sphere being measured in terms of the brightness and area of the comparison window and the distance of the comparison photocell from that window.

Using the same notation as before, the flux through the face of the comparison photocell of radius h_c, at distance r from the window of brightness B_0 and area A_0 is

$$\bar{F} = \pi B_0 A_0 \left(\frac{h_c}{r}\right)^2.$$

Now in the null condition, when the film aperture is part of the sphere wall and a balance is attained, the flux through the comparison cell face is

$$\bar{F}_0 = \pi B_0 A_0 \left(\frac{h_c}{r_0}\right)^2.$$

And when a lens is being measured, at balance

$$\bar{F} = \pi B_1 A_1 \left(\frac{h_c}{r}\right)^2$$

where it is assumed that both the brightness and the area of the comparison window may be changed to accommodate the scale used on the instrument. Forming the ratio of these two fluxes as on the other side of the lamp house, and since the corresponding fluxes measured on the two sides are assuredly proportional to each other, the working equation becomes in terms of primary parameters

$$\frac{1}{(2f_n{}^*)^2} = \frac{\kappa}{(2f_n)^2} = \frac{F}{F_0} = \frac{\bar{F}}{\bar{F}_0} = \frac{B_1 A_1}{B_0 A_0}\left(\frac{r_0}{r}\right)^2.$$

It was discovered in practice that the areas involved at the rear of the lamp house were so small that the highly desirable use of circular diaphragms whose diameters could be measured accurately was infeasible, so it becomes necessary to use neutral filters to modulate the light on passage from the null condition to the condition of measurement. Under these circumstances, if T represents the transmittance of the filter

$$B_1 = TB_0 \quad A_1 = A_0$$

and the working equation becomes in terms of observable parameters

$$\frac{1}{(2f_n{}^*)^2} = \frac{\kappa}{(2f_n)^2} = \mathrm{T}\left(\frac{r_0}{r}\right)^2$$

from which either the transmittance κ of the lens can be derived immediately, using the engraved aperture stops, or the effective photometric f/number can be found. The relationships involved are obviously

$$\kappa = T\left\{2f_n \frac{r_0}{r}\right\}^2 \text{ and } f_n{}^* = \frac{r}{2r_0\sqrt{T}} = \frac{f_n}{\sqrt{\kappa}}.$$

Practical Realization.—The apparatus built in our laboratory is composed essentially of an integrating sphere to collect the flux, a lamp house containing a 500-w lamp, and a movable bracket for

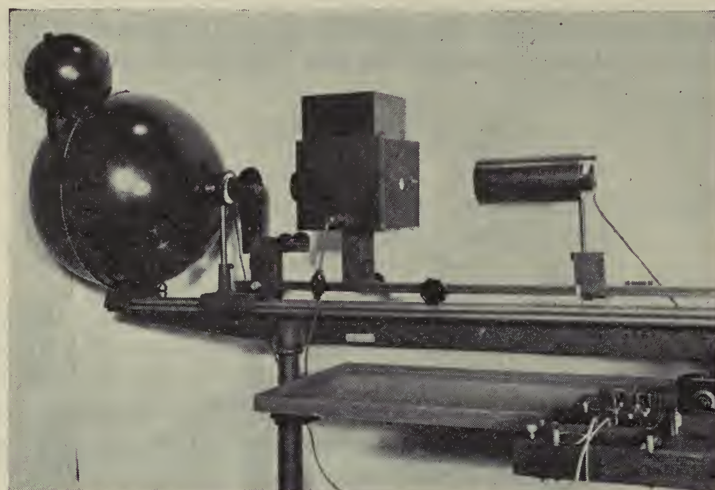

FIG. 1. The lens calibration equipment.

the comparison photocell, whose position can be measured with respect to the rear of the lamp house.

The integrating sphere is 21$^3/_4$ in. in diameter, and from a previous user we inherited a 3-in. port with a cylindrical projection which serves very well to support the sphere on the optical bed. The sphere is baffled inside so that no direct light from either the aperture or the intercepted beam can strike the photocell. It was found that this still was insufficient, and that the addition of an auxiliary collecting sphere of 8-in. diameter sufficed to smooth out the distribution of light so that the same conditions of illumination on the photocell prevail whether the lamp house aperture is in place, or the flux through a lens is being measured.

The lenses under test are supported in a hinged rack and pinion mount with a set of adapters for different lenses. The lens support can be swung out of the way of the lamp house for establishing r_0. In focusing a lens, a plane mirror is fastened over the front of the lens and the reflected image focused to sharpness on the matte white face of the lamp house muzzle. This insures that the film aperture is in the focal plane of the lens.

The lamp house is built with a projection fitting into the integrating sphere. This projection is long enough to place the depolished opal glass film aperture flush with the sphere wall, the condition required for accurate measurement of the total flux issuing from the film aperture. The face of the projection is lacquered with the same matte white lacquer used inside the sphere and lamp house. Forced draft ventilation cools the lamp. The rear of the lamp house bears another depolished opal glass aperture, whose exposed area can be varied by the insertion of masks. This area faces the comparison photocell, which is carried on a movable bracket carrying an index, so that the distance between the comparison aperture and the comparison cell can be measured. These distances are read on the calibrated optical bed.

In the preliminary stages of this development it was decided to use the logically unobjectionable photometric balance system of measurement. With this system and two sufficiently well-matched photocells, virtually all sources of primary photometric and electric inaccuracies can be caused to drop out of consideration, leaving a sound physical measurement of flux.

This whole system of measurement is more suitable in the laboratory instrument than in factory equipment, because of (*a*) the several separate measurements entering into the evaluation, and (*b*) the fatigue of the photocells. The cells fatigue inevitably at different rates, and the balance point shows a drift in time whose rate is variable with illumination level, which requires a delay in reading increasing with the desired accuracy.

Two Weston Model *594 YRO* type *3* photoelectric cells are used in the balanced current bridge type of circuit, which is superior to the traditional potentiometric bridge because of the nonlinear response curve of the barrier layer cells. The circuit is shown in Fig. 2.

It was quickly discovered that the edges of the originally preferred apertures which were used to modulate the flux on the comparison cell side of the lamp house could not be made sufficiently nonreflecting to

serve for a geometrically defined modulator in the required diameters of the order of one mm. Furthermore, these small apertures emphasize the local inhomogeneities in brightness of the second opal source.

For these reasons it was felt that the light could be modulated more accurately and reproducibly by means of neutral filters altering the brightness of the fixed aperture. Evaporated metal neutral filters of very flat spectrophotometric characteristics were used to accomplish this end. These filters are inserted in a holder between the comparison aperture and the photocell, and have been found to serve very well. The filters are so oriented that the reflected light from the comparison aperture falls clear thereof.

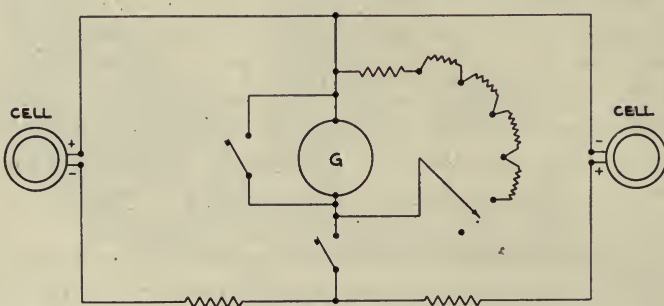

FIG. 2. The electrical circuit.

To gain a measure of the suitability of the independently calibrated filters for this application, a series of measurements was made with a set of filters whose transmittances were accurately measured in visible light. A set of blank apertures was placed in the lens holder at a definite distance from the film aperture, and the flux measured in the customary way. The mean transmittance of the blank apertures under these circumstances was 0.992, demonstrating the feasibility of using the independently measured transmission values with the barrier layer cells.

In practice, densities of the order of 2.5 are needed, which are difficult to measure with accuracy on standard equipment. The present apparatus as designed can be adapted to the measurement of the transmittances of filters of this density fairly easily by suitable modulation of the flux through the front of the lamp house, but it proved expedient to measure the factors of the denser filters by using blank apertures.

The consistency attained in a series of measurements is easily 8 per cent in transmittance, or $^1/_{10}$ stop,[9] and in careful work there is no trouble in attaining $^1/_{20}$ stop. The methods required to improve this consistency, and through it the accuracy of the equipment, are straightforward.

The flux radiated from the film aperture when it forms part of the sphere wall is mathematically equivalent to the flux through a perfect lens of aperture ratio $f/0.5$, the theoretical maximum. Our technique is a generalization of the method using an arbitrary standard blank aperture at a given distance from the film aperture, since our standard stop (0.5) is optically defined.

The method, then, is absolute, depending however on the measurement of the transmittance of the neutral filters used to modulate

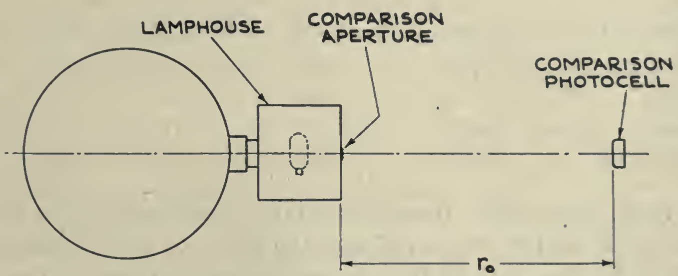

FIG. 3. Disposition for measurement of r_0.

the brightness of the comparison aperture. This can be done in the same equipment as used for the lenses without begging the question, or more expediently by calibrating against blank apertures. (The filters could be eliminated entirely with a fixed comparison aperture by using the inverse-square law, if very bulky equipment were acceptable. A range of at least 100:1 in the comparison aperture-photocell distance would have to be provided.)

A series of Baltar lenses of different focal lengths was measured with the following results:

	f_n	2.3	2.7	2.8	4	5.6	8	11
152-mm $f/2.7$ *BS 972*	f_n^*	...	2.97	...	4.04	5.70	8.30	11.38
Filmed Nominal 0.93	κ	...	0.83	...	0.98	0.96	0.96	0.93

152-mm $f/2.7$ *BF 2564* Unfilmed	f_n*	...	3.32	...	4.46	6.30	9.13	12.6
Nominal 0.75	κ	...	0.66	...	0.78	0.79	0.77	0.76
100-mm $f/2.3$ *VA 5884* Filmed	f_n*	2.57	...	2.98	4.15	5.66	8.19	12.37
Nominal 0.90	κ	0.80	...	0.94	0.93	0.98	0.95	0.79
100-mm $f/2.3$ *VA 5596* Unfilmed	f_n*	2.98	...	3.35	4.82	6.64	9.63	14.01
Nominal 0.63	κ	0.59	...	0.70	0.69	0.70	0.69	0.62
40-mm $f/2.3$ *BF 4256* Filmed	f_n*	2.70	...	2.96	4.13	5.86	8.03	11.07
Nominal 0.90	κ	0.74	...	0.92	0.97	0.91	1.00	0.99
40-mm $f/2.3$ *BF 4211* Unfilmed	f_n*	3.10	...	3.38	4.65	6.31	9.12	11.27
Nominal 0.66	κ	0.56	...	0.70	0.76	0.78	0.77	0.89

In those cases where the transmittance was measured at certain stops by aid of two neutral filters, the mean of the measurements is reported. The "nominal" value of the transmittance is the value measured on a transmissometer of conventional design. The values

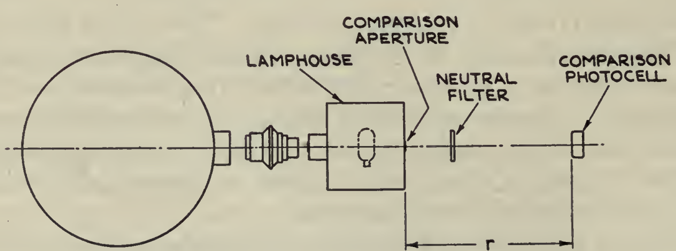

FIG. 4. Disposition when the flux through a lens is being measured.

in the table above include all sources of inaccuracy of setting of the diaphragm except that of backlash, since the diaphragms were all set from the same side (from the larger apertures). Notable in these results is the fact that without exception the transmittance over the film aperture is markedly lower at the maximum opening than at any other stop.

It is clear that the method here described provides information regarding only the "photometric efficacy." It is *per se* insufficient to standardize the measure of transmission (photographic f/number or "t/number"). This can be achieved through an arbitrary choice of transmittance, such that the measure of transmission is sufficiently close to present practice. From our observed transmittances and from the calculated values for lenses with six to eight air-glass surfaces a value in the range 0.60 to 0.75 would be close to current practice.

The proposal made by Berlant[4] is essentially the one made here.

ACKNOWLEDGMENT

The author wishes to acknowledge his indebtedness to Dr. W. B. Rayton, Director of the Scientific Bureau, at whose request the problem was undertaken, and whose ever-resourceful interest has been a continual source of encouragement. He wishes also to acknowledge the help given in many discussions with Dr. K. Pestrecov, and the assistance of Mrs. M. Tarplee in making tedious readings, and that of the Misses L. Frey and B. Marble in reducing the observations and in making numerous auxiliary computations.

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[5] The term "transmittance" is used for the ratio of the light transmitted to the light incident in accordance with the Optical Society of America Committee on Colorimetry Report, *J. Opt. Soc. Amer.*, **34,** 4 (Apr. 1944), p. 184.

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[8] WALSH, S. W. T.: "Photometry," Constable (London), 1926, p. 102.

[9] As here used, a fractional stop is understood to mean the ratio given by the fractional power of $\sqrt{2}$, the ratio between two geometrical full stops; *e. g.*, $^1/_2$-stop difference corresponds to the ratio $2^{1/4}$ between the fractional stops, $^1/_{10}$ stop $2^{1/20}$, *etc.*

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A NEW FILM FOR PHOTOGRAPHING THE TELEVISION MONITOR TUBE*

C. F. WHITE** AND M. R. BOYER†

***Summary.**—A film which is specially adapted for photographing images on the P-4 monitor tube surface has been prepared. Optical sensitization is adjusted to yield peaks of sensitivity within the blue to yellow spectral region corresponding to the emission of the P-4 screen. Resolving power of the film has been found of controlling importance when used in 16-mm size and this factor has affected the choice of emulsion for this purpose. The film may be employed either as a negative or reversed.*

As soon as the cathode-ray tube came into use in the laboratory, it became obvious that records of the traces would be most valuable. In the past, numerous articles have been written on the photography of cathode-ray tube traces; Morse,[1] Feldt,[2] and recently Goldstein and Bales,[3] have reported on the various films suitable for this type of photography.

A specific application arises in the motion picture photography of the *P-4* phosphor screen at an exposure time of $^1/_{60}$ of a second as required by the present 525-line television transmission. This should be accomplished with currently available lenses, at reasonably small apertures, and with tube voltages which allow adequate tube life.

Resolving Power.—In numerous 16-mm records taken of pictures on the *P-4* tube, it was noted that films now commonly sold as "high speed" did not give satisfactory pictures. Apparently this resulted from lack of resolution of the picture currently transmitted on 525-line television. This is surprising since a study of the published resolving power figures on currently available 16-mm films indicated that films of lowest resolution were theoretically capable of resolving all the transmitted lines. This is shown by the following calculations.

On a 525-line transmission 10 per cent is lost owing to blanking time, leaving the net received lines as 473. Taking these on a 16-mm

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** Research Division, †Sales Research Division, Photo Products Department, E. I. du Pont de Nemours & Co., Inc., Parlin, N. J.

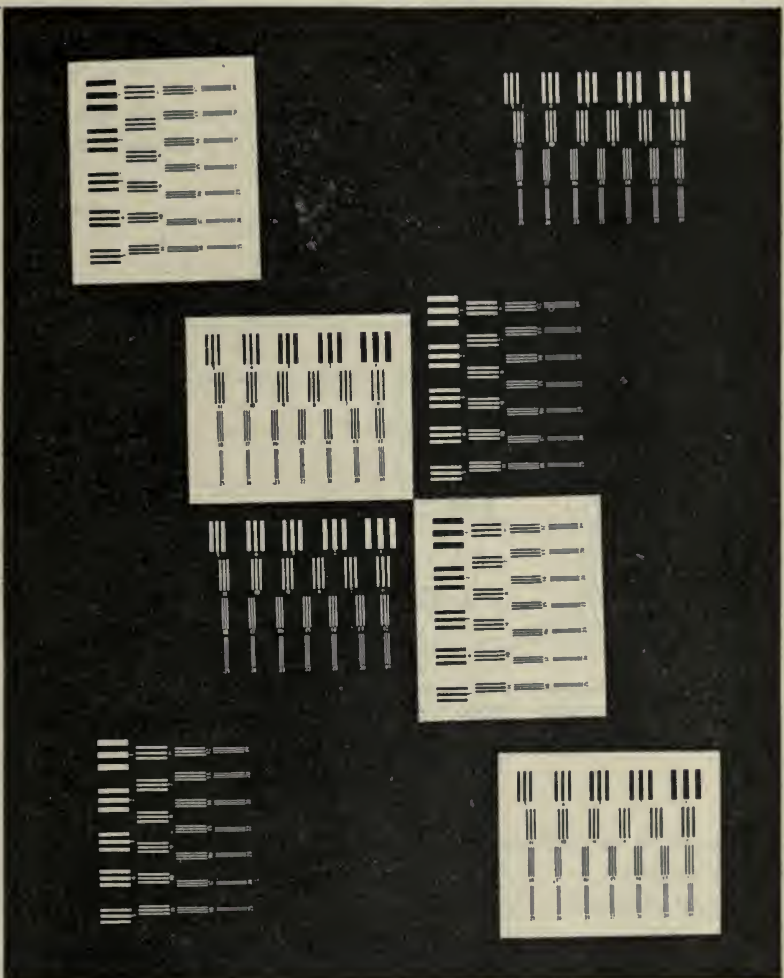


FIG. 1.

film, and using the American Standards Association[4] standard projector aperture height as 7.2 mm the required resolution of the film is 66 undivided lines per mm. Since all film data on resolution are given in double lines, or a black line plus an equivalent white space, the "photographic resolution" required of the 16-mm film is 33 lines per mm. This is considerably less than the published resolution of the highest speed film.

One explanation for the apparent discrepancy between the observed facts and the estimate formed on the basis of published figures

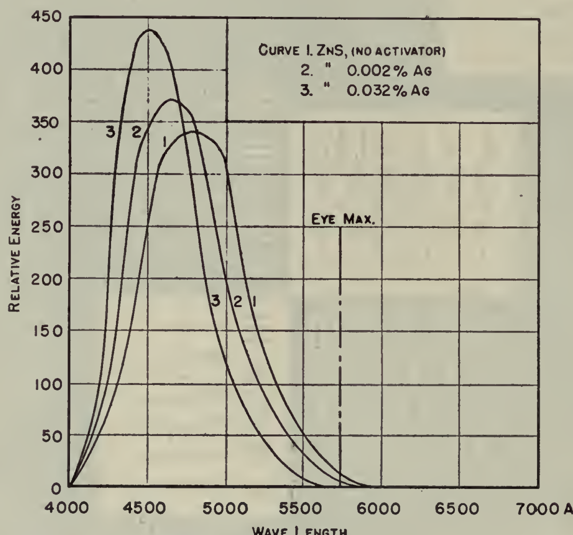


FIG. 2.

seemed to lie in the method of determining resolving power in photographic emulsions.

When an emulsion is evaluated for resolution, the object to be photographed is normally one of high contrast, of the order of 200:1. It is usually composed of black lines on a transparent background or white lines on an opaque background or some combination of the two. A conventional resolving power chart is shown in Fig. 1.

However, in considering the contrast of pictures on the television tube, Beers[5] states that for a 441-line picture the contrast of large areas can be considered as 50:1 and for small areas as 10:1.

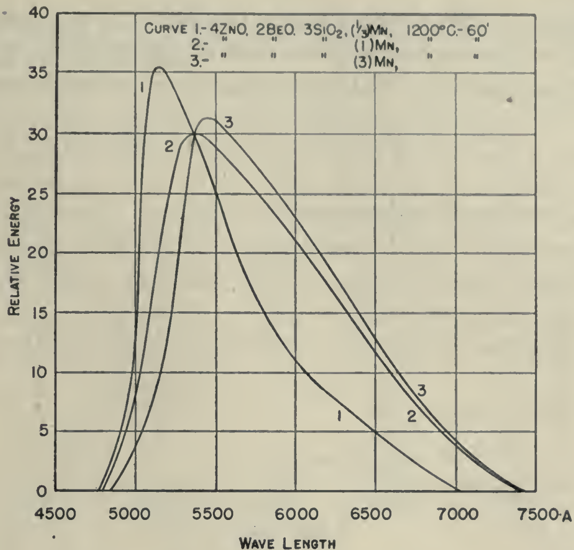

CURVE 1.- 4ZNO. 28EO. 3SIO2. (⅓)MN, 1200°C.- 60'
2.- " " " (1)MN, " "
3.- " " " (3)MN, " "
RELATIVE ENERGY
WAVE LENGTH
4500 5000 5500 6000 6500 7000 7500-A

FIG. 3.

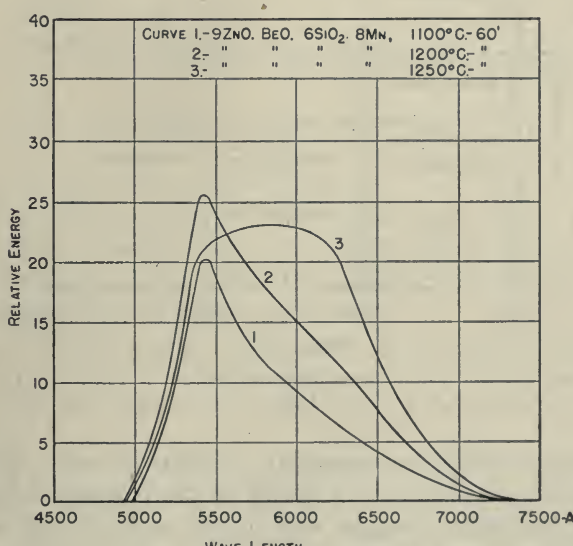
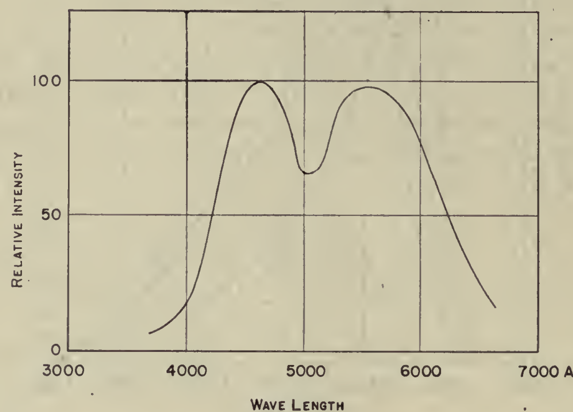

CURVE 1.- 9ZNO. BEO. 6SIO2. 8MN, 1100°C.- 60'
2.- " " " " 1200°C.- "
3.- " " " " 1250°C.- "
RELATIVE ENERGY
WAVE LENGTH
4500 5000 5500 6000 6500 7000 7500-A

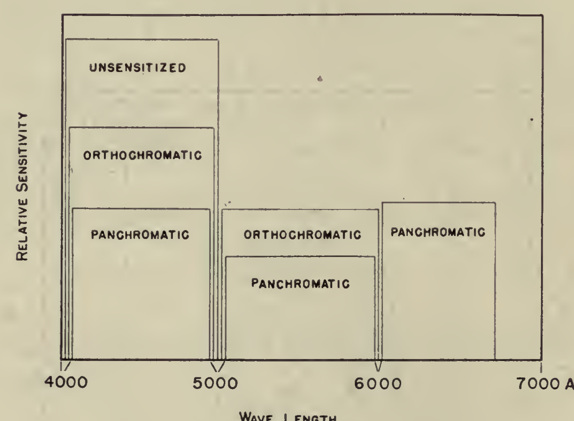
FIG. 4.

This figure 10.1 for small areas was probably not based upon areas so small as to approach closely the limit of resolution of the systems and a decrease below the 10:1 figure would be expected in any system,



SPECTRAL DISTRIBUTION OF THE EMISSION RADIATION OF A P-4 SCREEN

FIG. 5.



Optical Sensitization

FIG. 6.

as the areas considered approach the resolution limit. In addition, the mathematical studies of Cawein[6] on the relation of contrast to television bandwidth suggest still further reduction in brightness ratio when increasing the number of lines transmitted from 441, for

which the figures were given, to the present 525 lines for equal total transmission bandwidths.

The requirement for the resolving power of an emulsion to photograph the 525-line television tube evolves as 33 lines per mm at contrasts well under 10:1. This is considered as of primary importance.

No mention has been made of the effect of the lens on resolution, because it has been assumed in this discussion that the lens will be good enough to take care of a resolution in excess of 33 lines per mm.

Exposure Time.—In most of the data previously published, the exposure time could either be long or extremely short, as compared with the exposure time required for recording the image on the television tube.

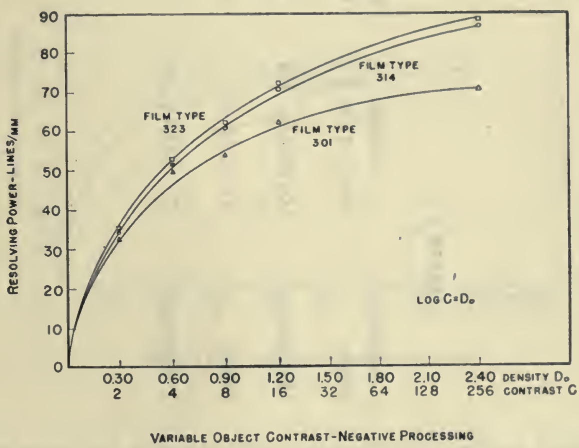


FIG. 7.

The recording of the tube image must be done in $^1/_{30}$ of a second. Longer times may be used so long as they are multiples of this figure, but the longer the exposure time, the more blurred will be any rapid picture action on the tube.

Speed.—Assuming that the exposure time is fixed at $^1/_{30}$ of a second, and the resolution at 33 lines per mm for a low-contrast object, the final requirement of a satisfactory emulsion is speed to the *P-4* screen.

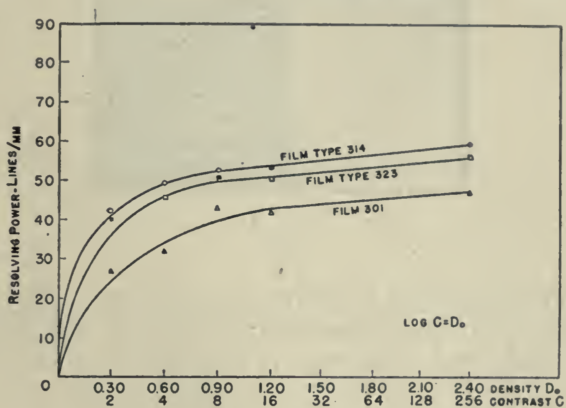
The *P-4* screen is chosen, not because it happens to be the type most commonly used in receiving tubes, but because at the present time the monitor tube must be set by eye for the best quality picture. Since judgment of quality is based on experience gathered from

TABLE 1

RMA Designation	Substance	Activator	Formula	Fluorescent Color	Phosphorescence (seconds)
P-4	*P-3* + Zinc sulfide	Silver	$Zn\,S.Ag + P\text{-}3$	White	Short 0.005
P-3	*Zinc* beryllium silicate	Manganese	$Zn\,BeSiO_3.Mn$	Yellow-Green	Medium 0.05
P-4	*Zinc* Sulfide	Silver	$Zn\,S.Ag +$	White	Short
	Zinc Beryllium silicate	Manganese	$Zn\ BeSiO_3.Mn$		Medium

viewing black-and-white pictures, it is most natural to work with a screen as nearly white as it is possible to obtain. It is conceivable that after a period of time it would be possible for a particular person to adjust a green or blue tube for picture quality just as readily as a white tube.

It is important to recognize that the Radio Manufacturers Association designation of a *P-4* screen has no meaning at the present time so far as spectral emission is concerned. As many as 20 *P-4* screens have been compared visually at one time and no two matched for color.



VARIABLE OBJECT CONTRAST-REVERSAL PROCESSING

FIG. 8.

Because emulsion speed is dependent on the spectral quality of the exposing radiation, the emission of the *P-4* screen must be considered. The difficulties involved will be recognized by a study of the following data taken from Krushel[7] (Table 1, Figs. 2, 3, and 4).

The RMA designation of a *P*-4 screen is shown in Table 1.

The curves in Fig. 2 show the change in emission spectra as silver activator is added to a *ZnS* phosphor.

Also, since the *P-4* screen is a mixture of *Zn* sulfide and *Zn Be* silicate, the change in emission of the *Zn Be* silicate as changes are made in the manganese activator concentration is shown in Fig. 3. Fig. 4 shows the relation of crystallization temperature to emission.

As can readily be seen from the above figures and from recognition of the fact that the proportions of *Zn* sulfide and *Zn Be* silicate are not

specified, the exact spectral emission of the *P-4* cannot be given. However, the ratio of ZnS to $Zn\ Be\ SiO_3$ is usually high and emission in the blue region will accordingly be high. Also, as higher tube

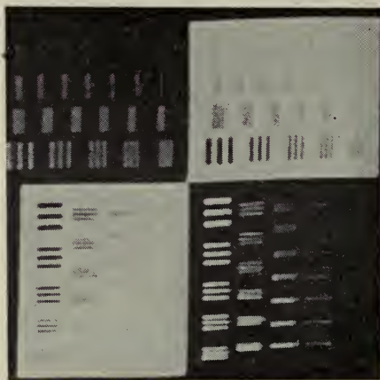
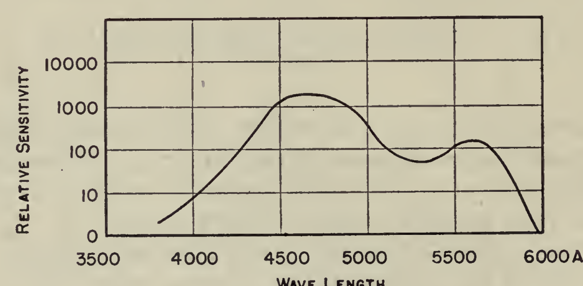


FIG. 9.

voltages are employed in the future to obtain greater brilliance the emission may be further shifted toward the blue. Finally, it can be said that the amount of emission in the red is very low. A typical

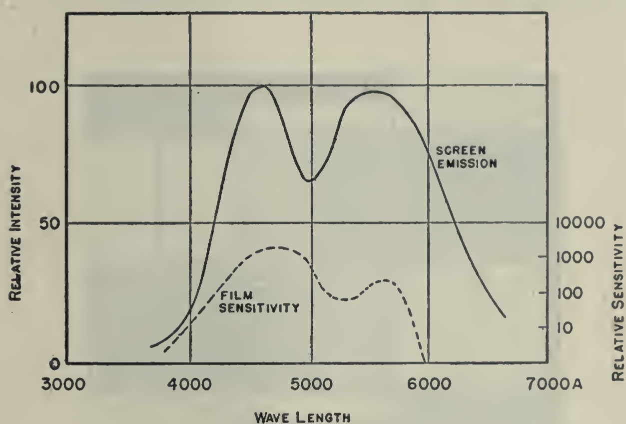


FILM TYPE 323-DAYLIGHT EXPOSURE
FIG. 10.

emission curve of a *P-4* screen is given in Fig. 5. Thus we find that the film for photographing images on such a surface should possess the highest possible blue sensitivity while taking full advantage of the green and yellow emission.

An additional factor influencing the choice of film for photographing the *P-4* tube is found in phenomena associated with optical sensitization of emulsions. As sensitization is carried farther and farther toward the red end of the spectrum, the blue sensitivity is often decreased. This is illustrated in a diagrammatic manner in Fig. 6. This factor, coupled with the foregoing information concerning tube emission, suggests the probability that an orthochromatic emulsion will be most suitable for photographing the *P-4* tube.

The above data establish to a certain degree the necessary resolution and spectral sensitivity of a motion picture film for photographing the *P-4* tube receiving 525-line television.



P-4 SCREEN EMISSION AND FILM SENSITIVITY

FIG. 11.

The following data indicate the way du Pont Emulsion type *323* meets these requirements.

Resolution with Type 323.—Published data (Sandvik)[8] show that the resolution of a film is markedly affected by the contrast of the test object and as we have pointed out, the object contrast in 525-line television is very low in regions of fine detail. Tests were made to obtain data on the specific emulsions used here, and processing was extended to include reversal development. Results are shown in Figs. 7 and 8. It will be noted that the resolution falls with the contrast, and that a higher white light speed film (type *301*) is worse than either types *314* or *323*, the ortho film.

Further tests were made by projecting into a television system the slide shown in Fig. 1. Great attention was given to maintain constancy in the system and from emulsion to emulsion. Photographs of the screen were taken and processed by reversal. A frame of the resulting picture on type *323* is shown in Fig. 9.

Labelling the four center blocks 1, 2, 3, 4 clockwise and beginning with the upper left-hand block, the resolving power for type *323* in lines per mm at $f/2.0$ is as follows:

Block 1—15 lines per mm (white vertical lines, black background)
Block 2—15 lines per mm (black vertical lines, white background)
Block 3—20 lines per mm (white horizontal lines, black background)
Block 4—20 lines per mm (black horizontal lines, white background)

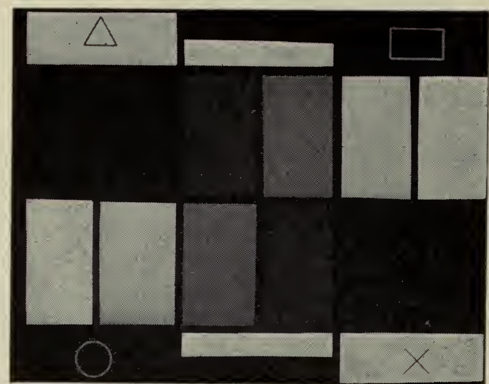


FIG. 12.

The difference in the resolution of the vertical lines (Blocks 1 and 2) and the horizontal lines (3 and 4) should be noted. This apparently is a confirmation of the calculations of Cawein and Hartley.

Considering the lowering in contrast owing to small areas and 525-line television, the recording of 20 lines per mm seems quite adequate and within 3 lines per mm of the observed image on the tube.

Speed of Type 323.—For the reasons given previously orthochromatization was used in type *323* and the spectral sensitivity is given in Fig. 10.

A combination of the response of the film and the emission of a *P-4* tube is shown in Fig. 11.

The speed of this emulsion was checked against du Pont Emulsion type *314*, which has an equivalent resolving power, by exposing to two different *P-4* screens, each at different voltages.

The first test was run on a television system by projecting into the iconoscope, by means of a slide projector, the slide shown in Fig. 12.

The system, with 15,000 v on the tube, was set to reproduce all shades in the 6-step wedge and measurements of the light output were taken at this setting by means of a photocell and microammeter. Keeping the same setting on the tube, and checking the intensity regularly, the two films were exposed in a 16-mm camera at three apertures. The films were reversed by machine.

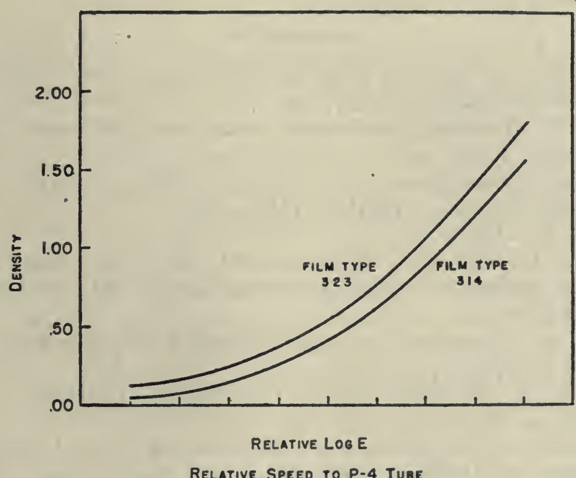


FIG. 13.

Table 2 shows net reversed density values for five of the steps recorded with an $f/2$ setting.

TABLE 2

Film	Net Densities				
323	0.24	0.36	0.98	1.60	1.71
314	0.39	0.54	1.21	1.80	2.00

A second speed check on a different *P-4* tube was run as follows:

A raster was put on the tube and a neutral density wedge placed in front of the exposing plate carrying the two films, types *314* and *323*

The films were exposed and developed as a negative. Fig. 13 is a plot of these results.

The above two tests indicate that the new ortho type *323* is at least one-half stop faster than the panchromatic type *314* to a *P-4* tube surface. These tests, coupled with actual motion picture recordings in a synchronized camera further indicate that the new film has ample speed to be useful under entirely practical television operating conditions.

Conclusion.—The above tests and practical picture tests indicate that du Pont type *323* is suitable for photographing the *P-4* monitor tube screen as it has a useful combination of resolving power and speed.

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TELEVISION REPRODUCTION FROM NEGATIVE FILMS*

E. MESCHTER**

Summary.—*The expected reproduction characteristics are examined for the cases where film is included as one step of the television process. Features of performance to be expected from both negatives and prints as image sources are predicted from average characteristics of elements of the television system. A dynamic test procedure for the investigation of the over-all reproduction curve involving film and television is described. Actual tests confirm the theoretical prediction that a negative film with a rising shoulder characteristic may provide superior television images.*

General Background.—The end objective of the television process is the production, on the picture tube, of an image which will be pleasing to the observer. Into this term "pleasing" enter both subjective factors, such as subject matter, state of observer's visual adaptation and contrast with nearby objects, and factors capable of exact objective specification of which scene brightness values, electrical and optical characteristics of the reproduction equipment are typical. It is the purpose of this discussion to examine some of the objective factors entering into the production of television images derived from photographic film as an intermediate, and particularly to study the conditions peculiar to the use of negatives for television broadcasting.

Objectively, the television process attempts to achieve "straight-line reproduction," in which, for every picture element, the logarithm of the brightness of the picture tube face divided by the logarithm of the brightness of the original scene is a constant. This ratio will be referred to as the over-all contrast of the system. For perfect reproduction the value of the over-all contrast is one and the brightnesses of the picture are proportional to the first power of the brightnesses of the original scene. However, this ideal often cannot be achieved in practice, particularly for outdoor scenes, where the average brightness range is too great to be reproduced accurately by the picture tube. Some compression of the picture brightness scale is

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** Research Division, Photo Products Department, E. I. du Pont de Nemours, & Co., Parlin, N. J.

necessary in such cases and the over-all contrast will be less than one. The discussion which follows is not limited to any particular value of the over-all contrast, but may be applied to the study of any degree of brightness scale compression or expansion.

Progress of a television image through the various electrical and optical stages of the reproducing system usually involves at least two nonlinear steps.

(*1*) The electrical output of the iconoscope (pickup tube) is not proportional to the amount of light falling upon it.

(*2*) The light output of the kinescope (picture tube) is not proportional to the electrical signal applied to it.

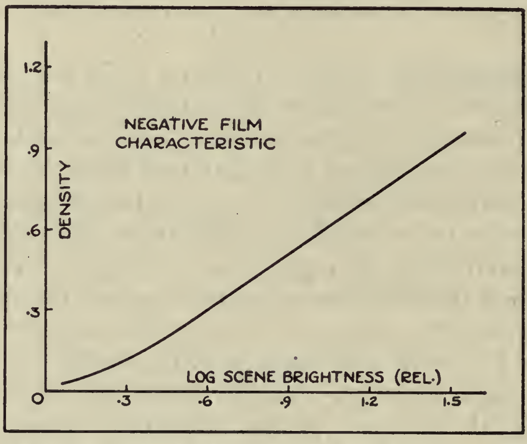

FIG. 1. Characteristic curve of a normal negative film.

However, when an original scene is imaged on the iconoscope and reproduced on the kinescope these nonlinearities are of a nature such as substantially to cancel each other out, and good quality reproduction with an over-all contrast of about one is obtained for scenes of moderate brightness range.

If the original scene is first recorded on a negative, printed on a positive, and this in turn imaged on the iconoscope, little change is introduced into the system. We know that the photographic process, properly carried out, gives a result in which the logarithms of the brightnesses of the projected image are closely proportional to those of the original scene, and nothing is done in this case to disturb can-

cellation of the equipment nonlinearities mentioned above. The final image obtained from scanning positive film should therefore be of a quality approximating that of direct pickup; it may perhaps exhibit a slightly different over-all contrast, depending on the exact film processing.

It is possible to record an original scene on a negative, image this negative on the iconoscope and, by modification of electrical connections (essentially reversal of amplifier polarity) cause a positive image to appear on the kinescope. This procedure is very attractive in

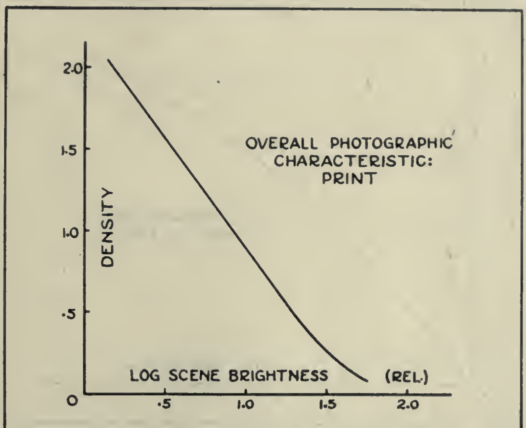

FIG. 2. Over-all reproduction characteristic of a negative and print system, showing density of print as a function of original scene brightness.

some respects, notably those of film processing speed and simplicity. However, the over-all characteristics of the electro-optical system are considerably disturbed by the polarity change; the curvatures of the kinescope and iconoscope characteristics that formerly tended to cancel now add, with the result that tonal values of the final image are appreciably distorted.

The exact manner in which this comes about may be demonstrated graphically, employing published average characteristic curves for film, iconoscope and kinescope. Fig.1 shows the characteristic curve of a negative film, in which density of negative has been plotted against log brightness of original scene. The distance 0 to 1.3 on the

abscissa corresponds to a range in brightness of 20 to 1, typical of a rather flatly lighted scene, but which also represents about the maximum brightness range which can be handled by present television systems.

If a print is made from this negative following normal cine procedures, the resulting film will have a characteristic similar to that of Fig. 2. Print density varies almost linearly with the logarithm of the brightness of the original scene; reproduction is reasonably faithful, with an over-all photographic gamma of 1.3.

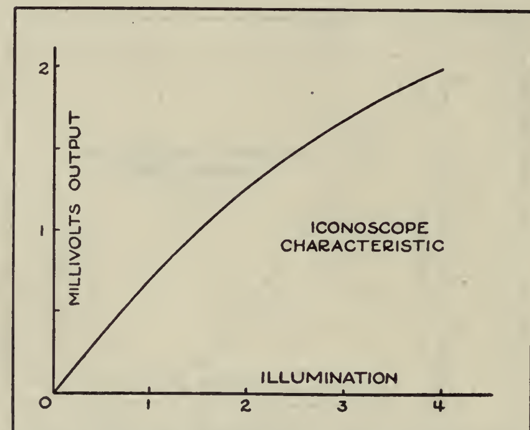

FIG. 3. Average iconoscope characteristic (after Zworykin and Morton).

Average characteristics of the elements of a television system are shown in Figs. 3,* 4, and 5.* Fig. 3 shows that the electrical signal produced by an iconoscope is proportional to the intensity of illumination only for low values of the latter; saturation effects cause distinct departures from linearity at higher illumination levels.

The amplifier (in which term we will include all electrical elements except the iconoscope and kinescope) is essentially linear, departures in a good system being rather small. The change from curve *A* to curve *B* of Fig. 4 represents the change in polarity required when switching from positive to negative film in the pickup. Change of

* Data from Zworykin and Morton, "Television."

slope of the amplifier curve represents a change in gain, while a translational shift corresponds to a bias adjustment.

The kinescope characteristic possesses even poorer linearity than that of the iconoscope; this is shown by Fig. 5, in which the curve exhibits no real straight line portion.

Another curve which will be helpful during the following discussion is that of Fig. 6. This is merely a graphical representation of a table of logarithms, giving directly the relation between the brightnesses usually used in describing iconoscope and kinescope performances

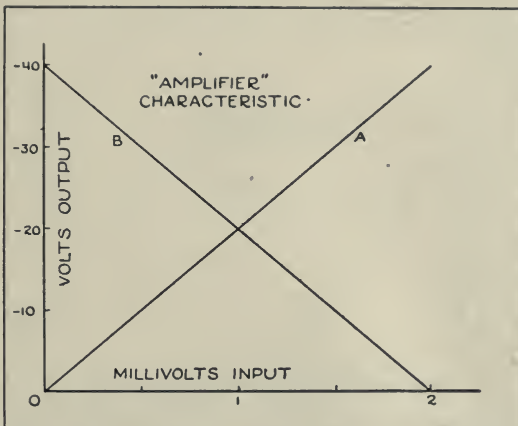

FIG. 4. "Amplifier" characteristics, showing method of indicating reversal of polarity.

and the "log brightness" values that are rather more convenient in discussing the original scene and its photographic aspects.

These several characteristic curves can be combined to give an estimate of the linearity of over-all reproduction from the original scene through the successive steps of film, projector, iconoscope, amplifier and kinescope.

Reproduction Through a Positive Transparency.—Consider first an original scene, the brightness values of which are represented as abscissas on the left quadrant of Fig. 7. The over-all photographic characteristic (introduced originally as Fig. 2) is represented by curve A in this quadrant, and print density values corresponding to original brightnesses may be read off directly. When this film is

placed in a projector the (logarithm of the) illumination from each element is directly obtainable from the density values, as indicated by the arrows from axis *Y1* to axis *Y2*. Variation in brightness of projector light is represented by merely sliding *Y2* along *Y1*.

Axis *Y2*, in turn, may be considered as one of Fig. 6. This curve already has been introduced to form the right quadrant of Fig. 7*a*. The combination of Figs. 2 and 6 may be represented more conveniently as in 7*b*, where the double ordinate axis has been eliminated but both density and log illumination scales have been retained.

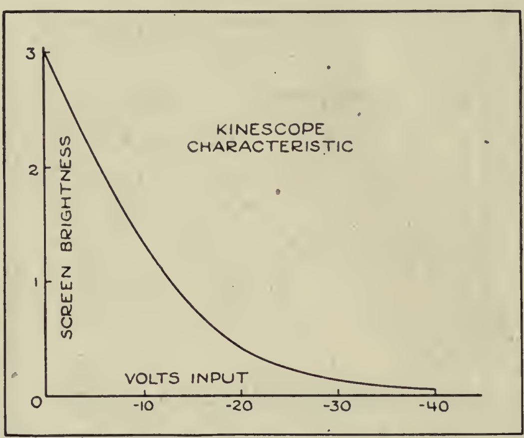

FIG. 5. Average kinescope characteristic (after Zworykin and Morton).

Continuing through the television system, the projector output becomes the iconoscope input. The iconoscope step can be added by placing the abscissas of Fig. 3 along X_1 of Fig. 7*b*, inverting Fig. 3 in the process. The result, shown in Fig. 8, represents progress from the original scene through the iconoscope.

Other elements of the complete system may be added successively. The iconoscope output becomes amplifier input, as in Fig. 9. Amplifier output is fed to the kinescope and becomes kinescope input as in Fig. 10. It is convenient to have final brightness on a logarithmic scale; the reintroduction of the "logging curve" of Fig. 6 on the kinescope output accomplishes this (Fig. 11).

The logarithms of the brightnesses of the original scene and of the reproduction on the kinescope screen now appear in the same figure,

along axes A-A and C-C of Fig. 11. These should form the two axes of a separate quadrant; this can be achieved by transferring values of A-A straight down to B-B as in Fig. 12, and by carrying values of C-C along the path shown to D-D.

The complete diagram is now ready for use. In order to represent a normal situation the projector light (which determines the level of iconoscope input) has been adjusted so that the entire useful range of the iconoscope is utilized, and amplifier gain has been set so that the whole inconoscope output swing corresponds to the useful kinescope input range (Fig. 13).

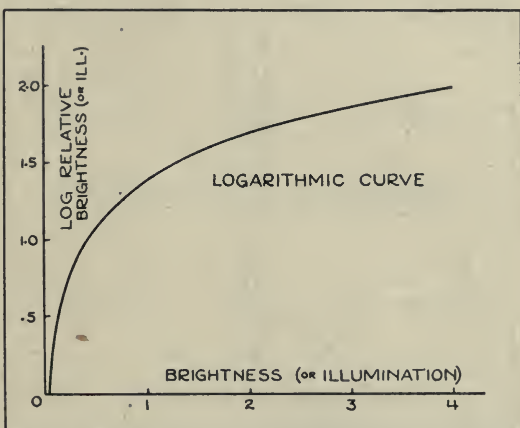

FIG. 6. Curve for conversion between brightness (or illumination) and log brightness (or log illumination).

To determine the over-all reproduction curve select any original scene brightness, represented by point M. Draw a vertical line to the film characteristic curve, then a horizontal line to the "delogging" curve, and so on to each curve successively as indicated by the arrows. Point N on the kinescope output scale corresponds to M; these two serve to locate P, which is one point of the over-all reproduction characteristic. The process is repeated, starting with other values (Q, R, S) on the scale of original scene brightness, to obtain other points of the reproduction curve (T, U, V). When carefully carried out on a large scale diagram the reproduction curve of Fig. 14 results.

For the positive transparency under consideration the values so determined closely approach the ideal straight line. The tonal scale is

somewhat expanded in the center of the range and compressed at the ends, but reproduction is good for the brightness range considered. The deficiency actually takes the form of some loss of shadow and highlight contrast and therefore detail, even for the limited brightness range considered. Attempts to reproduce scenes of greater tonal range will of course introduce more serious losses at the ends of the scale.

Reproduction Through a Negative Transparency.—The graphical procedure carried out for the case of a positive transparency may

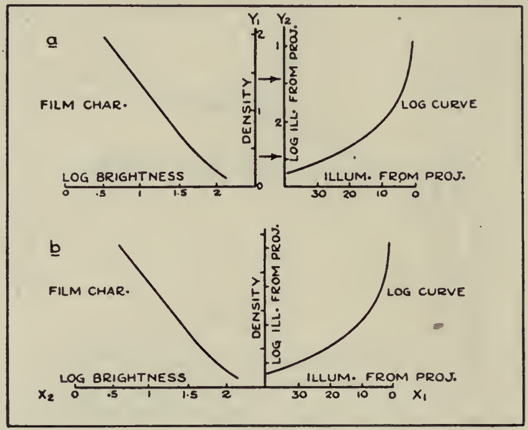

FIG. 7. Combination of Figs. 2 and 6 into one diagram, from which can be found illumination from the projector as a function of log brightness of original scene.

be applied to the study of transmission from a negative with only very minor change in the details of the diagram. The film characteristic in section *A* of Fig. 15 is now that of a negative instead of the over-all negative and print combination, and the amplifier polarity of section *B* has been reversed from (*a*) to (*b*).

The over-all reproduction characteristic *C* obtained when this is carried out for a normal negative of gamma 0.7 presents a number of interesting features. In the first place, the slope of the straight line portion is almost exactly correct, a somewhat surprising and certainly very fortunate result. From this one may conclude that negatives

of normal contrast characteristics should be about right for television transmission.

Second, the contrast decrease in the shadows which was observed for the positive case is no longer present; shadow detail should therefore be improved when the transmitted image is derived from a negative.

Third, there is a rather more serious loss of highlight contrast (and therefore detail) than when positives are employed. This highlight loss appears to be the most serious defect associated with the use of

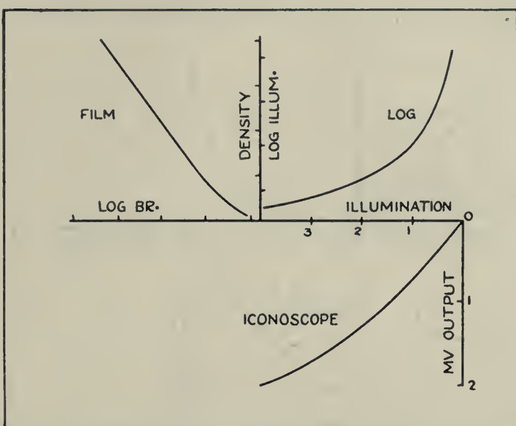

FIG. 8. Further combination of individual characteristic curves, representing progress through the iconoscope.

ordinary negatives. It appears distinctly worthwhile to seek means of correction, so that a high quality image may be achieved simultaneously with the other negative conveniences of processing speed and simplicity.

By far the simplest solution, from the motion picture viewpoint, is to have the television engineers design an amplifier of special characteristics, the insertion of which during the transmission of negatives will eliminate the distortion in question. The television engineers assure us that this can be done, on paper at least, but there appears to be some sentiment to the effect that they already have enough trouble without inventing special amplifiers to please the motion picture engineer.

Another "paper" solution, based solely on the graphical procedure under discussion, is shown in Fig. 16. If a negative slightly softer than normal is used, and if the projector light is adjusted to use only the high illumination end of the iconoscope characteristic, and if the amplifier gain and bias are adjusted to still fill the kinescope input scale with the resulting signal, then the over-all reproduction curve turns out almost exactly perfect. However, increased noise from the increased gain is only one of the drawbacks which make this solution a rather impractical one.

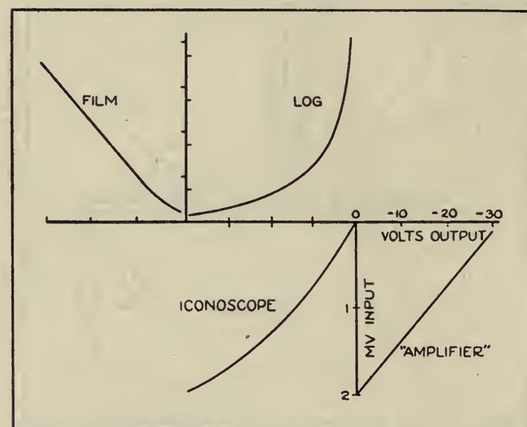

FIG. 9. The amplifier characteristic has been added to the film-projector-iconoscope combination.

An important element of the system which can be varied at pleasure within certain limits is that of the film characteristic curve. It is possible to discover the shape of the film characteristic required for accurate reproduction by inverting the original graphical procedure, inserting the desired straight line in the over-all reproduction quadrant and treating the film as the unknown. The mechanical procedure for accomplishing this, following from point to point through the various elements of the system, is exactly the same as before.

The result, the negative film characteristic required for accurate objective reproduction, is shown in Fig. 17. At low brightness levels the straight-line characteristic is retained, but higher contrast is introduced in the highlights to compensate for the loss experienced with

film exhibiting the standard straight-line curve. Formulation of a negative stock with such a rising shoulder is entirely possible and has much to recommend it as the best solution to the problem of obtaining improved television images from negatives.

Experimental Verification of Theoretical Predictions.—The conclusions concerning the nature of the reproduction characteristics to be expected from the transmission of positive and negative transparencies have been checked experimentally through the kind cooperation of F. J. Bingley, Chief Television Engineer, Philco Radio

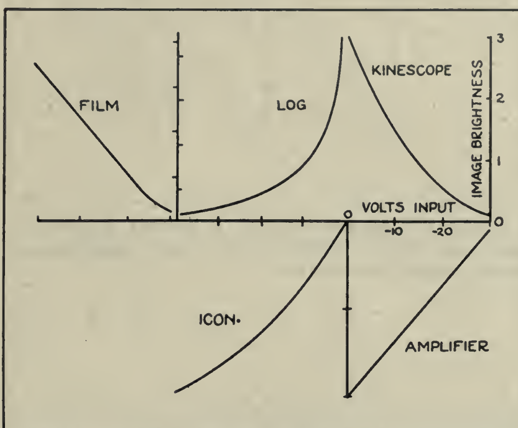

FIG. 10. Addition of the kinescope characteristic permits determination of image brightness as a function of log brightness of original scene.

and Television Corporation. It should be pointed out that these tests are purely of an exploratory nature, having been carried out on the monitor tubes of one station, for a limited number of scenes and for only one group of control settings. However, the general method is a dynamic one and is directly applicable to more thorough studies.

The "original scenes" were high-quality transparencies; relative brightnesses of various picture elements were easily determined by simple density measurements. These transparencies were placed on an illuminator and photographed on du Pont Superior *2* in a standard 35-mm cine camera. The negatives received a standard type of development and normal prints were made on du Pont Fine Grain Positive type *225*. A long-range transparent gray scale composed of

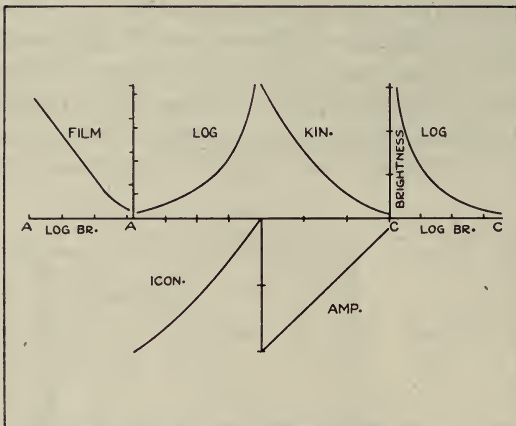

FIG. 11. Introduction of a second logarithmic curve puts scene brightness and image brightness on similar logarithmic scales.

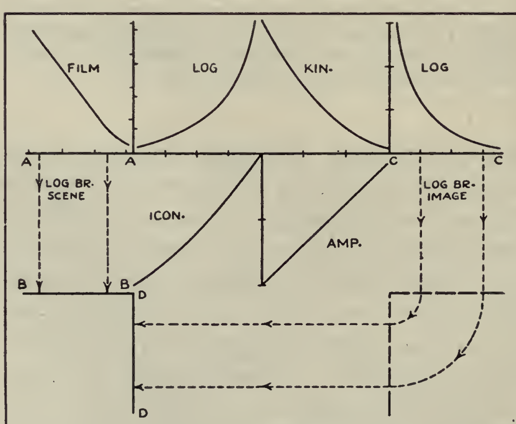

FIG. 12. Log scene brightness and log image brightness are now on the two axes of one quadrant for convenience in determining the over-all reproduction characteristic of the entire system.

simple blocks was also photographed on the same illuminator and prints prepared. The use of such blocks insured areas in the cine frame of a size sufficient to permit convenient density measurement.

Two rolls were then prepared for television scanning, one negative and one positive. Each scene was about 100 ft in length, which gave ample time to adjust the electrical controls to obtain the best possible quality on that particular subject, and each was followed by 50 ft of gray scale.

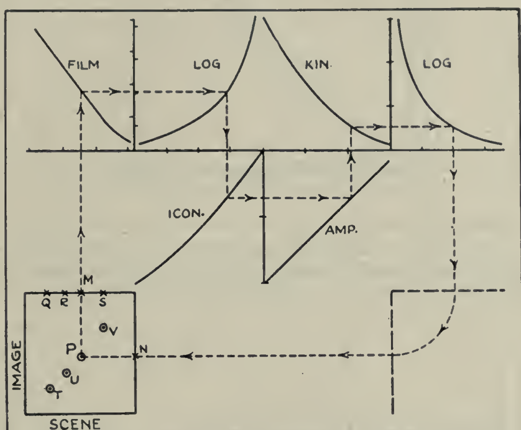

FIG. 13. The geometrical method of determining a point on the over-all reproduction characteristic is indicated: following the arrows through the characteristics of the successive stages of the system locates *N* corresponding to the starting point *M*.

Previously calibrated illuminated wedges were placed on either side of the monitor tube and a 5 × 7 camera was focused to include both the monitor and these standard illuminated gray scales.

The test procedure was then to run the cine material, adjusting controls to obtain the most pleasing quality on each scene. At the end of the scene the controls were left fixed when the cine gray scale appeared, and the gray scale image together with the standard scales beside the kinescope were photographed on a single piece of du Pont X.F. Pan. A record was made in this manner for each scene of each roll, comprising both positive and negative inputs to the system High agitation development of the 5 × 7 films permitted determination of absolute brightness levels of the kinescope face by simple den-

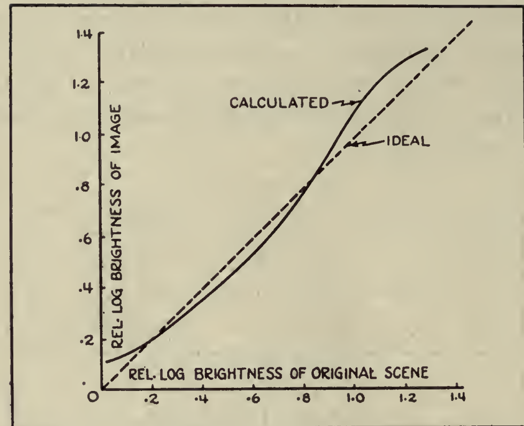

FIG. 14. Graphically predicted over-all reproduction curve of a television system employing positive film, compared with ideal reproduction.

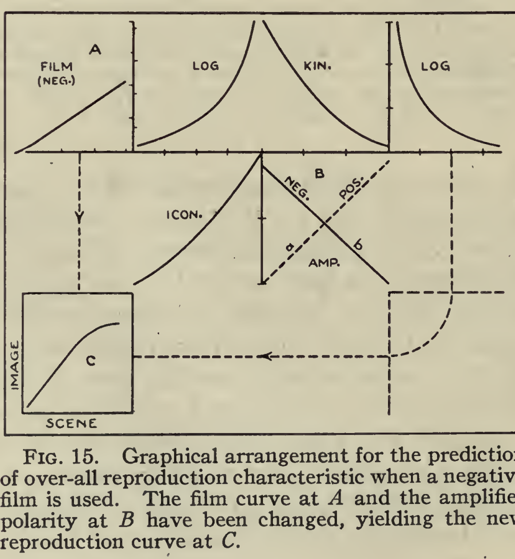

FIG. 15. Graphical arrangement for the prediction of over-all reproduction characteristic when a negative film is used. The film curve at *A* and the amplifier polarity at *B* have been changed, yielding the new reproduction curve at *C*.

sity comparison with the image of the standard wedge. These data, taken in combination with the relative brightnesses of the original scene, give an indication of the over-all reproduction characteristics of the photographic-electro-optical system. The general method is of special interest since it is a true dynamic test, carried out under actual operating conditions. It does not involve the insertion of glass slides, auxiliary projectors or alternate light sources.

The results are shown in the graph of Fig. 18, in which logarithms of kinescope brightnesses have been plotted against the logarithms of

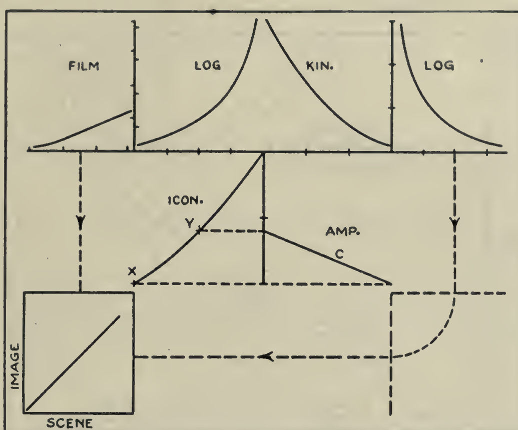

FIG. 16. A theoretically possible method of obtaining straight-line reproduction via a negative. Film gamma is low, only the high illumination portion of the iconoscope characteristic is used and amplifier gain has been increased.

the relative brightnesses in the original scene. Reproduction by way of cine positive is rather better than expected, as shown by the good straight-line characteristic. The decrease in contrast for the highlights when standard negative is used is very evident, confirming the predicted performance. Visual estimates of picture quality agreed with these calculated results; images from the negative film were superior in shadow detail but rather poorer in the highlights. Qualitatively, this failing is of a nature to be remedied by a rising shoulder negative as predicted in the earlier section of this discussion.

It should be re-emphasized that this represents a limited series of tests, and that such elements as the exact placing of these curves can be affected by projector light brightness, negative exposure, kine-

scope beam current and many other factors. However, it appears that the curve shapes may be regarded as truly representative of the general performance to be expected.

Practical picture tests of experimental negative materials embodying the rising shoulder characteristic have given very satisfactory results in a number of locations, indicating that the basic reasoning and first series of tests were sound. A complete quantitative evaluation based on the procedure described above has not been possible up to the present time; the recent reallocation of frequencies has made

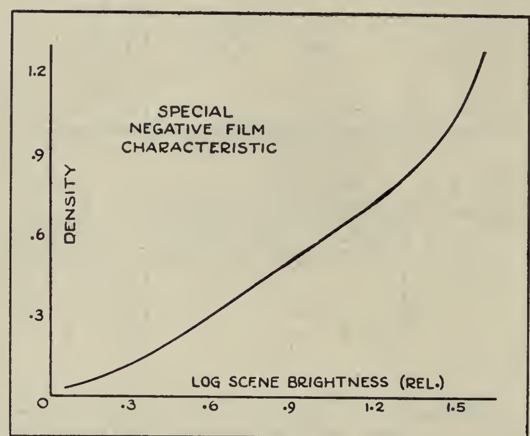

FIG. 17. Special negative film characteristic required for straight-line reproduction if gain and projector output are to remain normal.

such tests not merely difficult to arrange, but actually impossible in many cases. However, it is hoped that the return of stations to the air will soon allow the performance of this experimental stock to be studied quantitatively under a variety of conditions.

Conclusion.—Theoretical considerations based on the published average characteristics of the elements of the television system and actual dynamic experimental tests indicate that superior results may be expected from the use of a rising shoulder negative as a source of images for television broadcast. Fortunately manufacturing methods of achieving such a film characteristic are known; the good quality images obtainable in this was to provide additional incen-

tive for the general study of the use of negatives for television transmission. These improved results can be obtained without throwing any added burden of equipment modification on the television engi-

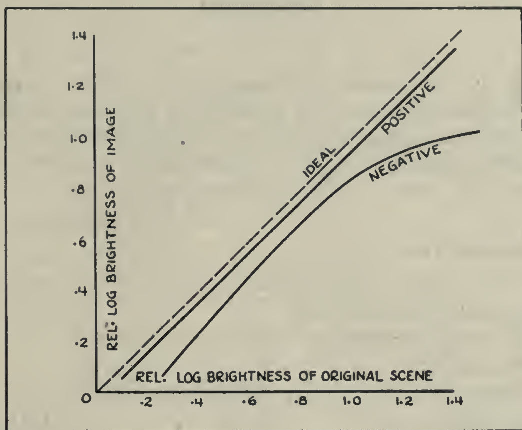

FIG. 18. Experimentally determined over-all reproduction characteristics of a television system using normal prints and normal negatives, compared with ideal straight-line reproduction curve.

neer. It seems likely that such negatives, offering high-quality images, will find a definite place in the television world, since they also offer the advantages of speed and simplicity of processing.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

27, 5 (May 1946)

Psychology and the Screen (p. 160) — H. A. Lightman

World-Wide Celebration Planned on 20th Anniversary of Sound Films (p. 162)

Survey of Current Processes of Color Kinematography in England (p. 164) — J. H. Coote

Soviet's War Documentary (p. 170) — A. Kaltsaty

27, 6 (June 1946)

Specialized Photography Applied to Engineering in the Armed Forces (p. 195) — P. M. Thomas and C. H. Coles

Miniature Camera Models (p. 202) — I. Browning

Russia Grabs German AGFA Plant, Process, Equipment (p. 206)

British Kinematograph Society, Journal

9, 1 (Jan.–Mar., 1946)

Presidential Address (p. 2) — A. G. D. West

Technicians' Ideas for Improving Equipment:

- Cameras and Studio Equipment (p. 5) — C. Vinten
- News Reel Equipment (p. 7) — D. Forrester
- Sound Recording (p. 8) — E. Williams and N. Daines
- Processing Equipment and Procedure (p. 9) — E. Thorne
- Projection and the Projection Room (p. 10) — R. Pulman
- Sub-Standard Equipment and Processes (p. 11) — G. H. Sewell
- Television in the Kinema (p. 13) — A. G. D. West

Newsreels in War-Time:

- The North African Campaign (p. 17) — T. Ashwood
- War Filming in the Far East (p. 19) — A. Tozer
- The Liberation of Europe (p. 21) — S. Bonnett
- The Norwegian Campaign (p. 26) — L. Murray
- Make-Up of Newsreels (p. 27) — J. C. Stagg

Electronics

19, 2 (Feb. 1946)

Design of Compact Two-Horn Loudspeaker (p. 156)	P. W. KLIPSCH

International Projectionist

21, 5 (May 1946)

Victor Animatophone 16-Mm Projector (p. 7)	L. CHADBOURNE
Elements of Projection Optics, Pt. II (p. 10)	A. MONTANI

21, 6 (June 1946)

Switzer Electronic Arc Control (p. 5)	G. W. SWITZER
Illusion of Depth in Motion Pictures (p. 8)	H. T. SOUTHER
Television in the Movie Theatre? (p. 14)	L. B. ISAAC
Basic Radio and Television Course, Pt. 24—Receiving Systems (p. 18)	M. BERINSKY

The Photographic Journal

86A, (Apr. 1946)

Technical Progress in Kinematography (p. 96)	R. H. CRICKS

SMPE

60th SEMIANNUAL CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL
Hollywood, California

OCTOBER 21–25, 1946

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HOTEL RESERVATIONS AND RATES

The Hollywood-Roosevelt Hotel, Hollywood, Calif., will be the Convention Headquarters, and the hotel management extends the following per diem room rates, European plan, to SMPE members and guests:

Room with bath, one person	$4.40–5.50
Room with bath, two persons, double bed	$5.50–6.60
Room with bath, two persons, twin beds	$6.60–7.70

Desired accommodations should be booked *direct* with Stewart H. Hathaway, Manager of the hotel, who advises that no parlor suites will be available unless confirmed by him. All reservations are subject to cancellation prior to October 14, and *no reservations will be held after 6:00 p.m.* on the anticipated date of arrival unless the hotel management has been advised otherwise.

HOUSING COMMITTEE

An acute housing condition exists in Hollywood and it is expected that most of the available reservations at the Hollywood-Roosevelt Hotel will have been taken by the time this issue of the JOURNAL reaches the membership. In order to be of assistance to members desiring room accommodations, the Pacific Coast Section has set up a Housing Committee under the Chairmanship of Past-President Herbert Griffin.

The Housing Committee expects to mail a return post card to all members outside of the Hollywood area on which the member may state whether he desires room accommodations and for what length of time. The returned cards will be checked against available reservations and an effort will be made to place Eastern and Midwestern members who plan to attend the Convention. However, the demand is very apt to exceed the supply and reservations will be made on the basis of "first come, first served." It will be of assistance to all concerned to have the cards returned as quickly as possible.

RAIL, PULLMAN, AND AIR ACCOMMODATIONS

SMPE members and guests who have received confirmed room reservations, should then consult local transportation agents as early as possible, and book their desired transportation accommodations immediately.

REGISTRATION

The Convention Registration Headquarters will be located in Room 201 on the mezzanine floor of the hotel, where Luncheon and Dinner-Dance tickets can be procured prior to the scheduled dates of these functions. Members and

guests are expected to register. The fee is used to help defray Convention expenses.

BUSINESS AND TECHNICAL SESSIONS

Day sessions will be held in the hotel, and evening sessions at locations away from the hotel, which will be listed in the preliminary, and final printed Convention programs.

Authors who are planning to present papers at the 60th Semiannual Convention should mail the title of their paper to the West or East Coast Chairman of the Papers Committee, or to the Society's New York Office, as soon as possible. As a prerequisite to inclusion on the program, authors' abstracts must be received by the Papers Committee by Sept. 1. Complete manuscripts *must* be submitted by Oct. 1, 1946. Only through your cooperation can a preliminary program be drafted early enough for publication in the industry trade papers and mailing to the membership at least a month prior to the Convention.

GET-TOGETHER LUNCHEON AND DINNER-DANCE

The Society will again hold its regular pre-war social functions and accordingly a Get-Together Luncheon is scheduled in the California Room of the hotel on Monday, October 21, at 12:30 P.M. The luncheon program will be announced later. Members in Hollywood and vicinity will be solicited by a letter from S. P. Solow, Secretary of the Pacific Coast Section, to send remittances to him for the Convention registration fee and luncheon tickets. Ladies are welcome to attend the luncheon.

The 60th Semiannual Dinner-Dance will be held in the California Room of the hotel on Wednesday evening, October 23, at 8:30 P.M. Dancing and entertainment. (Dress optional.) A social hour for holders of Dinner-Dance tickets will precede the Dinner-Dance between 7:15 P.M. and 8:15 P.M. in the Hotel Terrace Room (Refreshments).

LADIES' PROGRAM

A reception parlor for the ladies' daily get-together and open house with Mrs. H. W. Moyse as hostess will be announced on the hotel bulletin board and in the final printed program.

Ladies are welcome to attend technical sessions of interest, also the Luncheon on October 21, and the Dinner-Dance on October 23. The Convention badge and identification card will be available to the ladies by applying at Registration Headquarters.

The ladies' entertainment program will be announced later.

MOTION PICTURES AND RECREATION

The Convention recreational program will be announced later when arrangements have been completed by the local committee. Identification cards issued only to registered members and guests will be honored at the following *deluxe* motion picture theaters on Hollywood Boulevard:

Egyptian Theatre
Grauman's Chinese Theatre
Hollywood Pantages Theatre
Hollywood Paramount Theatre
Warner's Hollywood Theatre

Technical Sessions Scheduled

Monday, October 21, 1946

	Open Morning.
10:00 a.m.	*Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Luncheon and Dinner-Dance tickets.
12:30 p.m.	*California Room:* **SMPE Get-Together Luncheon.** Program announced in later bulletins.
2:00 p.m.	*Aviation Room, Hotel Mezzanine Floor:* **Opening business and Technical Session.**
8:00 p.m.	**Evening Session:** Location to be announced later.

Tuesday, October 22, 1946

	Open Morning.
10:00 a.m.	*Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Dinner-Dance tickets.
2:00 p.m.	*California Room:* **Afternoon Session.**
8:00 p.m.	**Evening Session:** Location to be announced later.

Wednesday, October 23, 1946

9:30 a.m.	*Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Dinner-Dance tickets.
10:00 a.m.	*California Room:* **Morning Session.**
	Open Afternoon.
7:15 p.m.	*Hotel Terrace Room:* A social hour for holders of Dinner-Dance tickets preceding the Dinner-Dance (Refreshments).
8:30 p.m.	*California Room:* **60th Semiannual Convention Dinner-Dance.** Dancing and entertainment. Program will be announced later.

Thursday, October 24, 1946

	Open Morning.
1:00 p.m.	*Room 201, Hotel Mezzanine Floor:* **Registration.**
2:00 p.m.	*California Room:* **Afternoon Session.**
8:00 p.m.	**Evening Session.** Location to be announced later.

Friday, October 25, 1946

	Open Morning.
2:00 p.m.	*California Room:* **Afternoon Session.**
8:00 p.m.	**Evening Session.** Adjournment of the 60th Semiannual Convention. Location to be announced later.

Note: All sessions during the 5-day Convention will open with an interesting motion picture short.

Important

Because of the existing food problem, your Luncheon and Dinner-Dance Committee must know in advance the number of persons attending these functions in order to provide adequate accommodations.

Your cooperation in this regard is earnestly solicited. Luncheon and Dinner-Dance tickets can be procured from W. C. Kunzmann, Convention Vice-President, during the week of October 13 at the Hollywood-Roosevelt Hotel.

All checks or money orders for Convention registration fee, Luncheon and Dinner-Dance tickets should be *made payable* to W. C. Kunzmann, Convention Vice-President, and *not* to the Society.

W. C. KUNZMANN
Convention Vice-President

SOCIETY ANNOUNCEMENTS

EMPLOYMENT SERVICE

POSITIONS OPEN

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

Motion picture studio in Bombay, India, has positions open for professional motion picture camerman with studio and location experience; sound recording engineer experienced in installation, maintenance and operation of recording equipment; motion picture processing laboratory supervisor; and professional make-up artist. Five-year contracts at favorable terms are offered to those qualified. Write or cable direct to Personnel Manager, Dawlat Corporation Ltd., Patel Chambers, French Bridge, Bombay 7, India, giving experience, etc., in detail.

New film production unit to be located at Athens, Georgia, needs film editor-writer and film director. Experience in 16-mm as well as 35-mm production desirable. Southern background or interest in South preferred but not essential. Write giving full details of experience, etc., to Nicholas Read, The National Film Board, Ottawa, Canada.

Photographer. Large manufacturer with well-organized photographic department requires young man under 35 for industrial motion picture and still work. Must be experienced. Excellent opportunity. Replies held in confidence. Write stating age, education, experience and salary to The Procter and Gamble Co., Employment Dept., Industrial Relations Division, Ivorydale 17, Ohio.

POSITIONS WANTED

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Honorably discharged veteran with 10 years' experience in projection and installation of projection and sound equipment, both for booth and back-stage. Prefer to locate in California, Oregon or Nevada. For additional details write F.A.N., Box 113, Holley, Oregon.

Cameraman, honorably discharged Army veteran, desires re-enter industrial, educational production with independent producer or studio. Experienced in 35- and 16-mm color and black-and-white. References and complete record of experience available. Write, wire or telephone T. J. Maloney, 406 Oak St., Ishpeming, Mich. Telephone 930.

Sound Recordist. Former Signal Corps sound instructor and Army Pictorial Service newsreel recordist-mixer, 35-mm equipment. Honorably discharged veteran, free to travel. Write Marvin B. Altman, 1185 Morris Ave., New York, N. Y. Telephone Jerome 6-1883.

16-mm Specialist. Honorably discharged veteran with many year's experience, specializing in 16-mm. Linguist. Available for special assignments. Write J. P. J. Chapman, ARPS, FRSA, The Huon, Branksome Hill Road, Bournemouth, England.

Cameraman. Veteran honorably discharged from Air Force Motion Picture Unit desires to re-enter industrial, documentary, or educational film production. Experienced in 35- and 16-mm, sound, black-and-white and color cinematography. Single, willing to travel. Write S. Jeffery, 2940 Brighton Sixth St., Brooklyn 24, N. Y. Telephone Dewey 2-1918.

Experienced and licensed projectionist and commercial radio technician desires employment with 16-mm producer as sound recordist. Thoroughly familiar with principles and practices of sound-on-film recording. Write F. E. Sherry, 705 1/2 West San Antonio St., Victoria, Texas.

We are grieved to announce the death of Leon Gaumont, Honorary member of the Society, on August 11, 1946, in Paris, France.

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

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(This page should be completely filled out by applicant in conformity with Qualifications and Requirements given on the opposite page for grade desired. References given should be members or nonmembers who will supply information on applicant's experience and serve as sponsors.)

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Address____

City____

Employer____

Occupation____

Grade Desired: Associate ☐; Active ☐

Education*____

Record of Employment* (list companies, years, and positions held)________

Other Activities*____

REFERENCES**

(Name)	(Address)	(City)
1		
2		
3		

The undersigned certifies that the statements contained in this application are correct, and agrees, if elected to membership, that he will be governed by the Society's Constitution and By-Laws so long as his connection with the Society continues.

Date______________19_____ (Sgd)__________________________

* If necessary, use additional sheet to give complete record.

** References should be members of Society. If not, supply two letters of reference from individuals acquainted with applicant's work.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 SEPTEMBER 1946 No. 3

CONTENTS

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Indexes to the semiannual volumes of the Journal are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL
OF THE
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HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 SEPTEMBER 1946 No. 3

SYNCHRONIZATION TECHNIQUE*

W. A. POZNER**

***Summary.**—This paper consists of an introduction describing the history of dubbing technique, a section describing the importance of sound perspective, and a detailed description of the dubbing method used by M-G-M International Films Corporation.*

M-G-M International Films Corporation greatly appreciates the opportunity created by the Society of Motion Picture Engineers to present this paper on the dubbing technique in general and, specifically, the technique employed in its studios. It must be made clear at the very beginning that there is no such thing as isolated dubbing technique. There is, however, a well-known motion picture technique, within which there exists a process that some call "dubbing" and others "synchronization." When the well-established and well-known technical methods of the motion picture industry are properly applied for the purpose of synchronizing or dubbing, a process is created which may be called dubbing technique. I would like to outline briefly how, in the last fifteen years, motion picture technique has progressed to a point permitting us to substitute voices, to transpose stories from one language to another, creating the illusion of reality, and thus enabling us to entertain greater and greater audiences.

If we bear in mind that one of the basic goals of the motion picture industry is to make the screen look alive in the eyes of the audience, we will more easily follow the problems that the dubbing process had to overcome.

History.—With the advent of the "talkies," the motion picture

* Presented Feb. 13, 1946, at a meeting of the Atlantic Coast Section of the Society in New York.

** M-G-M International Films Corporation, New York.

industry had to face several problems, one of the most important being the problem of the language. The technique of producing motion pictures, the acting, everything had to be changed. There was the necessity for a different tempo. The subtitles and cut-in titles of the silent movies were replaced by speech. That speech could not be understood by audiences speaking a different language. The only means of overcoming that difficulty was to use the superimposed title method, which still had the defect of not being a means of conveying *all* of the dialogue nor *all* of the story, and distracted the public from watching the action. It was only a partial answer to the problem.

In 1931 some major American companies decided to experiment with another method. Similar experiments, by the way, were carried out simultaneously by German firms, and consisted of trying to substitute the original language of the picture with a foreign language, synchronizing the foreign language with lip movements of the actors on the screen. It is interesting to note that the approach to the problem in the USA was entirely different from that of the Germans. The Germans decided that this was a purely technical problem, which, therefore, had to be solved by highly technical means. In this country it was just *a* problem that was to be solved by whatever means proved to be the best.

Mechanical Guide Method.—In trying to transpose a motion picture by only technical means, the German method fell into exaggerated mechanical details. No picture can be technically perfect if it is not the result of collective work of a group of people with creative minds. The same holds true for any and all motion picture processes and, therefore, for the process of dubbing.

The German process consisted basically of:

(*a*) A method which permitted detection of the speech components of the original version by electromechanical means which gave a design similar to a cardiogram.

(*b*) Transcription of this speech and its graphic representation on a paper or film in a manner similar to the one used for transcribing lyrics and music on a music sheet, the only difference between such transcripts and music sheets being that instead of having the notes, there was a graphic representation of the syllable, and—underneath—instead of having the lyrics there were the syllables themselves.

After establishing this type of strip or guide, the text was translated. Great care was taken that each syllable, word, and sentence

of the new language coincided exactly, syllable for syllable, with the original text. The new language was then transcribed on clear, transparent film or on a large disk, and was spaced exactly in the same manner as was the original dialogue on the "guide." The guide bearing the dialogue in the new language was then projected on a screen simultaneously and in synchronism with the picture print from which its "cardiogram" was detected.

The text appeared from right to left (horizontal projection) or counterclockwise (on a rotating disk) and the actors were to read their lines as soon as a syllable hit a determined point on the screen. The result was a more or less perfect synchronization of the new dialogue with the lip movements of the original version, but that synchronization was not a true one. The length was there, but the phonetic emphasis and the emphasis of thought and of interpretation were totally absent.

It could not be otherwise, since no actor can interpret his part if he reads it at a speed dictated to him by something like an electric signboard. There is a doubt in our mind that anybody could interpret aloud and with dramatic effect the news bulletins that appear on the Times Building, if he had to read each syllable exactly at the time that it reaches the 42d Street corner.

Of course, this method presented the advantage of giving a synchronized dialogue at a very low cost. The preparation required the work of only a few people—no studio time was involved; therefore, there is no studio overhead—all of which accounts for a very low cost. But it also had a big disadvantage, since there are very few actors who can read their lines from a mechanical guide with any real effectiveness. Those few who are able to do so, became, as some people say, "expert dubbers."

As an example, one actor alone has dubbed the voices of George Raft, Edward Robinson, Cary Grant, Dick Powell, and Paul Muni. We all have admiration for these stars and we know that each one of them has a personal approach to the part he plays. No one would expect William Powell to play Zola, or Paul Muni to play Nick Charles, since the temperament and interpretation of every actor is different and personal. It is, therefore, inconceivable that an actor, good as he might be, could impersonate several outstanding performers, although the excuse is often heard that "he does not fit the part, but he is a good synchronizer," which means that he can read in synchronism.

Of course, these are only the basic elements of the mechanical guide method born in Germany and later developed in France, Spain, and the USA. This method has improved since, mainly because the theater-going public was dissatisfied and demanded a better product.

On the other hand, the method of detecting the original dialogue became more perfect and gave not only the graphic representation of syllables, but also the phonetic emphasis of the word within a sentence. The technicians learned how to differentiate a labial sound from an explosive; the difference between the vowels and the consonants, and the equivalent sounds such as *d* and *t*, *a* and *i*, *s* and *l*, giving the writers a somewhat greater flexibility for translation. But the basic mistake of that mechanical guide method still remains; *i.e.*, the actor is still merely reading his lines, and not often giving them much dramatic effectiveness.

Visual Synchronization Method.—The other method we should like to call the visual synchronization method.

The problem of substituting the original dialogue by a new one in a different language was approached from the viewpoint that such substitution should be done on the basis of emotional equivalence. The new dialogue, of course, should be in synchronism with the lip movements of the actor appearing on the screen, but, what is more important, the emphasis of the new dialogue and its meaning should coincide with the emphasis of the facial expressions and gestures that the audience follows.

Since there were no mechanical reference points to guide the work of people who tried to make such language conversions, most of this work was done in the experimental, empiric way.

The new dialogue had to be created simply while projecting the picture on a screen, on a cutting moviola, or on a projection moviola, and trying to read the lines of the new dialogue simultaneously with the dialogue of the original version. Soon enough it was found out that it was impossible to write a dialogue in such a fashion, since the speed at which words are delivered on the screen is much too great, and the reels in their regular form are too long. The standard projection machine and the cutting moviola were discarded; the former because of the time loss involved in rethreading it, and the latter because of its small picture size. The so-called projection moviola with reverse drive was used and reels were run back and forth, projected on the screen, while the writer tried to adapt the new dialogue line by line.

Such a process involved a tremendous amount of time loss and could not give the necessary assurance for synchronization. It also became apparent that no actor could memorize his part for scenes that lasted several minutes. It was at this point that the idea of an endless loop was born. This meant that every picture to be synchronized had to be cut into short scenes, leader had to be added at the beginning and end of scenes, forming an endless band of film, and such film band projected for as many times as it was necessary for the writer to write the dialogue and later for the actor to enact the scene.

Special equipment that could safely allow a projection of such type of loops had to be devised. A technique of breaking a complete motion picture into scenes had to be developed.

It might seem that such breakdown can be done arbitrarily, and, let us say, all scenes *can be* 50 ft long, 100 ft long, or X ft long. It is not really as simple as that. It must be remembered that an attempt is being made to re-create an illusion and therefore the emotional aspect of each scene composing the picture must be taken into consideration. The work of the writer, the actor, and the sound technician must be facilitated to the greatest extent to enable them to achieve their goal. Therefore, when in practice a motion picture is broken down into loops, their lengths vary from as little as 20 ft to as much as 150 ft.

There is no average length. It is dictated by the amount of dialogue that the writer has to adapt and the actor to memorize, as well as by the dramatic emphasis of the scene. It is impossible to break up a love scene in the middle, or a hysterical scene at an arbitrary spot, just for the sake of the loop's length.

It would also involve needless difficulties to combine in the same scene several camera angles, since each camera angle may or does call for a different acoustical interpretation.

Another very important factor which must not be overlooked in comparing the two methods is one of talent. Since the emphasis of the visual synchronization method, from the start, was on the dramatic value of the new version, it was extremely important to find actors who could really "get under the skin" of their counterparts of the original version. The voices in the new language version had to match the voices of the actors of the original one, but even more, the manner of speech, the manner of articulation, to a certain extent the mouth formation, had to be very similar.

If an identical voice could not be found, it was necessary to find a voice that would have the same general characteristics—perhaps in slightly higher or lower register, but still being dry if the voice of the original actor was, or warm in the event that the original actor's voice was such.

To summarize in brief: the visual synchronization method first requires a lot of imagination on the part of the writer, then makes it imperative for the actor to know his lines by heart and to be able to interpret them at a tempo which is dictated to him by the action that he is observing on the screen.

To this description of the two processes, I should like to offer you my conclusion. The mechanical guide method was far superior to the visual synchronization at the early stage of the game, but when this last process started adopting the generally known motion picture technique, it outdistanced its competitor by a very great margin.

Sound Recording.—Before going into a detailed description of the visual synchronization method as employed in the studios of M-G-M International, it is necessary to point out the extreme importance of the sound recording technique.

At this time I would like to quote a paragraph by Wesley Miller from "Motion Picture Sound Engineering," published by the Research Council of the Academy of Motion Picture Arts and Sciences:

"In the natural world, certain combinations of objective elements of sight and sound are familiar to us. It is only when our expectations are disturbed that we commence to wonder and to investigate. The character of a sound informs us of its proper source and time of origin. We know what to expect when we start out to identify that source and we have but to trace it back to find it.

"The recording medium introduces a new element—time. The reproduced sound may no longer be traced directly to its source in point of time. Any period may elapse between the original inception and the final reproduction. The identification of source becomes a voluntary effort, and a multitude of questions arise to perplex us in the technique of the reproduction system. The motion picture craftsman desires to create in his product an illusion which plays upon the imagination of his audience to make them forget these artificial factors. By the many artifices at his command he may often transport them from their own sphere to the entirely new surroundings which he provides for them at the screen."

This quotation clearly indicates how much creative ability is generally expected from the sound engineer and this is even more true in the case of a sound engineer working on the production of a synchronized version.

There is no difference between the recording apparatus employed in direct production and in synchronization. The mixer panels, volume indicators, loudspeakers, amplifiers, recording machines are identical.

However, the problems that the sound engineer must solve are multiple. In a recording auditorium with a given acoustical characteristic, he has to create an illusion that would match an infinity of acoustical interpretations. The scene that is recorded takes place in the hall of a railroad station. The next, in a boudoir. Then come scenes in an airplane, in the woods, in the mountains, in a business office. Each and every one of them calls for different acoustics, but the sound engineer is still in the same auditorium. He cannot move his recording equipment by means of a magic wand from one surrounding to another. Nevertheless, he must give the movie-going audience the illusion of doing just that.

Another problem: a big close-up appears on the screen. You see only the actor's head. You expect to hear his breath; you expect almost to hear his mouth move. In the next shot you can barely see people; they are at the end of a long hall, but the auditorium remains the same size. It is up to the ability of the sound engineer to create the illusion of space.

Of course, a question may arise in the reader's mind: "Well, after all, how about the man who gives you a variety of illusions during radio broadcasts?" Far be it from me to call his job an easy one, but how much easier it is compared to the one of the sound engineer who works on a synchronized version! Do not forget that he is not supposed to record sound of the quality that you would hear in *any* big hall, but it must be of a quality that in your mind will correspond to the big hall that has already been photographed, and that you actually see on the screen.

The distance between you and the actor on the screen must be faithfully reproduced and the acoustical illusion must be exactly of the same order as the visual one. The engineer must relate the actor's voice to what is seen on the screen. If an actor on the screen, while speaking, has his back toward the public and then turns around, the quality of the sound must change, to underline that

movement, but it must change *exactly* at the time that the public feels such change as a natural necessity. It cannot be too early and it cannot be too late. That is why the imaginative capacity of the recording engineer who is entrusted with creating a new sound track for a synchronized version is of basic importance to the success of the whole enterprise.

M-G-M International Films Corporation.—Having established the basic differences and the basic requirements of both synchronization methods, I would now like to give you an idea of how this work is performed in the studios of M-G-M International.

It was found a good policy to organize production units, the number of such teams being in direct proportion with the program of the studio. Our experience has been that a high-standard production requires an average of three months' continuous work from time of inception until a finished product can be thrown on the screen. Therefore, one team, allowing for overlaps in production, can complete five to six pictures in a year. As we go along, we shall describe in detail all of the basic steps and all duties and responsibilities of the members of each production team.

To begin with, such a team is composed of four permanent members and one semipermanent one, the permanent members being the director, the assistant director, the film editor, and the sound engineer. The semipermanent one is the dialogue writer.

Preparation.—The first step is preparation for production. When a motion picture in its original version reaches the synchronization studios of M-G-M International, and a production of the new language version is decided upon, the motion picture is screened for all members of various production teams, supervisors and studio manager personnel.

Such screening has two purposes: first, to give the writers and directors an opportunity to express their choice; second, to give the technicians of our studios the opportunity to become acquainted with the type of product coming from Hollywood (or from abroad) and to familiarize themselves with the pictures they will have to work upon.

A meeting will be held after the screening and the production assigned to a team. At this time, cutting, action, and dialogue continuities have reached our studios.

With a continuity in hand, the director, the assistant director, the writer, and the supervisor will screen the feature at least twice

more. They will mark on the continuity the proposed scene breakdown, they will discuss such scene breakdown after each screening until a decision is reached. In addition to that, the writer will indicate on his original dialogue continuity the phonetic emphasis of sentences, the basic pauses or peculiarities in pronunciation of each actor. The film editor will take note of any special information which might be required in the preparation of inserts, titles, opticals, *etc.* When the continuity is broken down we say the picture has been "cued" into loops and we number such loops consecutively from one to whatever the last number might be. Several copies of cued continuities are prepared, one going to the production supervisor, the others to all members of production teams.

Following a loop breakdown, the film editor will break down the film into individual scenes, splicing the beginning and end of each scene into a loop, which is numbered in agreement with the scene numbers appearing on the continuity.

The production supervisor will prepare a character breakdown chart. Such chart indicates in how many scenes and in which ones each character will appear. A chart of that sort is therefore extremely useful in preparing a shooting schedule, a daily program for recording.

But before any actors can be called, a decision must be reached as to who those actors are going to be, which is the work of the director, his assistant and the casting department.

Casting.—When synchronizing American pictures into a foreign language, it has been our aim to find exact voice counterparts for each important American actor. In order to do so, we have conducted an extensive series of tests. For our Spanish version program, tests are being made currently in New York, Hollywood, and throughout Central and South America.

Such actors' tests are transcribed on phonograph records and forwarded to our Casting Department. The records are played back and the voices of the Spanish-speaking actors are typed.

To begin with, the types are very broad, such as young or old, high-pitched or low-pitched, pleasant or unpleasant. Then each type is reviewed again. For example, deep, middle-aged, male voices will have pleasant and unpleasant voices among them, will have character and lead types, and eventually a voice is found that sounds like Edward Arnold's. In order to make sure, we will compare the recording of this voice with a film or disk recording of Ed-

ward Arnold himself. If this comparison is satisfactory, this Spanish actor will become the permanent counterpart of Edward Arnold in all our Spanish versions.

It goes without saying that the acting ability of all prospective Spanish performers is thoroughly examined even prior to a detailed analysis of their voice quality.

After having applied such a process of talent classification for about two years, our studios have today successful counterparts of most of the M-G-M stars for their Spanish versions. Nevertheless, the scouting for talent is a continuous task and is being carried out daily by our casting department. Cross-reference files, index card files are established. Each Spanish actor who ever played a part in our studios has such a card. Each identifiable actor who played a part in the original version of any picture synchronized in our studios has a card. On the Spanish actor's card the name of the original actor for whom he substituted in the Spanish version appears, as well as the title of the picture and the name of the character. On the original actor's card similar information is recorded, the only difference being that it will bear the name of the Spanish actor who substituted his voice for the original one.

Once such a system is established, the casting problem in its major part becomes a problem of classification. A detailed original cast for each picture to be synchronized is received by our casting department. Referring that cast to our cross-index files, we can easily find the counterparts of Spencer Tracy, Ingrid Bergman, Agnes Moorhead, Donald Crisp, *etc.*

Should a new actor appear in a forthcoming production, advance information will reach us and a thorough search will be conducted until a proper Spanish voice is found for such an actor.

The Shooting Schedule.—Once the casting is finished, it becomes necessary to prepare the shooting or recording schedule.

The preparation of such a schedule is the responsibility of the production supervisor, in co-operation with the director.

The first step will be to establish the basic sequences that compose the picture as a whole. Then, to place such sequences in their chronological order, and finally, to analyze whether each sequence, short or long, can be recorded in one day's work.

One must be very careful not to overestimate the working capacity of actors and directors. It has been found that an average of 30 scenes or loops can be satisfactorily recorded during a normal day's

work, provided that no actor has more than 20 scenes in the day.

The director will see to it that the dramatic continuity is not interrupted by breaking down one sequence into two or three, and that the continuity of the development of each character is kept in its chronological sequence, which is not necessarily the continuity of the motion picture in its final form. Such nonchronological development is found in the flash-back technique as used in such pictures as *The White Cliffs of Dover*, *Mrs. Parkington*, and *Waterloo Bridge*, where the chronological development of the characters does not coincide with the continuity as it appears on the screen.

Writing the New Dialogue.—As important as all the other problems might be, the one of writing dialogue for the dubbed version is really the most important. We stated previously that our goal was to create a new language version which will retain all of the characteristics of the original one, refracted in the specific medium of the new language with all its peculiarities, traditions, and idiosyncracies.

When two characters appear on the screen, one having a Bronx accent and the other a Middle Western one, everybody knows where these people come from and what their background is. They are definite types. But how do people in Colombia and Peru know what the Bronx is, and why should they understand that there is a difference between Bostonian and Texan English? The how and why are the questions to be answered by the writer who prepares the new dialogue. The answer cannot be given by the interpretation of the actors, since not only the accents vary in English, but basically the structure and the texture of the language are different. The actor can only handle the language material that is given to him. He can express it more or less successfully, but if the style of his dialogue does not correspond to the character, the discrepancy creates an artificial type.

The writer, therefore, must possess a deep knowledge of the language in which he writes. He is not a mere translator. He really does re-create the types which once appeared in the original version. But he also has another problem to solve. The dialogue must be spoken in synchronism with the lip movement of the original character. The basic thought expressed in the original dialogue must be retained. It is a very tedious and difficult problem to solve. A study in phonetics, a deep knowledge of phonetic equivalents must accompany an idiomatic knowledge of the language.

A mind that can take advantage of any situation provided by the

action on the screen, by every off-screen dialogue, by every shadow, every movement on the screen, is one of the basic requirements for successful dialogue writing. I should like to give a few examples of how writers overcome the difficulties of such problems.

The lines below are part of a prayer spoken by a young girl in a French convent. The writer, though not making a literal translation, has preserved the spirit of the original, as well as its rhythm. In both languages the basic phonetic values are the same—meaning, particularly that in both versions the labials fall in the same places—and that the new lines are in naturally expressed English. Here are the examples:

Délivrez-moi/de l'angoisse/d'où je s/uis plongée.
Deliver me/from the anguish/that is/upon me.
Protégez-nous d/e votre main.
Protect us now and/ever more.

Technically, the process of writing the new dialogue can be boiled down to the following elements:

As you remember, the writer screens the picture with the original continuity in hand, on which he makes notes indicating basic pauses, phonetic emphasis of sentences and the off-screen dialogue, *etc.* Usually the writer requires three screenings before he can assimilate the picture and gather all the pertinent information. Having the picture clearly in mind, the writer then translates the dialogue, keeping the basic conformation of his text as closely as possible to the conformation of the original. In other words, the tempo of the dialogue, the length of sentences are kept as closely as possible to those of the original.

The writer definitely does not translate word for word, or sentence for sentence, since this would produce artificial speech. We all know that nouns, adjectives, and verbs do not present themselves in the same sequence in, let us say, a language of the Anglo-Saxon group and in a language of the Latin origin. Trying to place the words in the same sequence as they appear in the original language would by necessity mean artificiality. Of course, this first draft of the new dialogue is by no means synchronized with the original. It is merely the basis which later on will be adjusted and transformed so as to become synchronized with the lip movements on the screen.

Some writers require an additional step in their work. The original dialogue is rerecorded from film onto phonograph records of

commercial size and speed, and the writer can play those records back on a pickup whenever he wants to check the length of a sentence, the manner and rhythm in which the sentence is pronounced, the emphasis, the speed, and the pauses that occur within the sentence.

After having prepared a final draft, the writer will discuss it with the director and the assistant director. It will be made sure that the characters have not been modified, and that all thoughts contained in the original have been clearly transposed into the draft.

It will be necessary at this point to check the synchronism of the new dialogue with the original action. For that purpose, the writer and the assistant director will screen the picture scene by scene, each scene being in loop form, and while the assistant director will enact every line of dialogue in synchronism with the action appearing on the screen, the writer will eventually rewrite, correct, and check the synchronization. The director will very often be present at this time, and all three men will discuss any change that might be necessary for synchronization. It has been our experience, however, that the synchronism is not so important as the naturalness, the fluidity of the dialogue.

However, by this we do not mean that any degree of synchronism is acceptable for a synchronized version. Should we face a situation where, in order to achieve a perfect synchronization, we would destroy the naturalness of our dialogue, we would discard such a solution, since the fluidity of the dialogue is a greater psychological factor in giving perfect illusion than the mechanical synchronization.

Such checking of dialogue necessitates two or three weeks of constant and tedious work for each feature. Once completed, the dialogue is discussed again by the members of the production team and the editorial staff of the script department. Should the subject call for strictly medical, naval, or military expressions, a technical expert's help is used. Once all these questions are clarified, the script is prepared with as many copies as necessary, and distributed to the cast and all members of the production team.

Recording the New Dialogue.—Once the script is ready, the cast is set, the recording schedule is established, and the technicians know the subject they are going to work on almost by heart, we can safely go into a studio and start recording.

Fig. 1 is a vertical section of a recording studio.

A recording studio should be a rectangular room approximately 40 ft long and 25 ft wide, and 16 to 18 ft high. At one end of such

an auditorium there is a screen. At the other extreme, in a room adjacent and separated by a large glass window, is located the sound recording control room. A projection booth, equipped with one or two standard projection machines with special loop magazines, is located above or alongside the control room. The control room should be as large as possible, to accommodate the necessary sound recording equipment, the sound engineer and one or two assistants. It is very important that the people inside the control room have an unobstructed view into the auditorium, and can readily observe the projection screen.

The auditorium should be acoustically treated for both soundproofing, in order to eliminate outside noises, and a minimum amount of reverberation. In practice, the deader the acoustics of such room, the better the results. However, it is desirable that the acoustic treat-

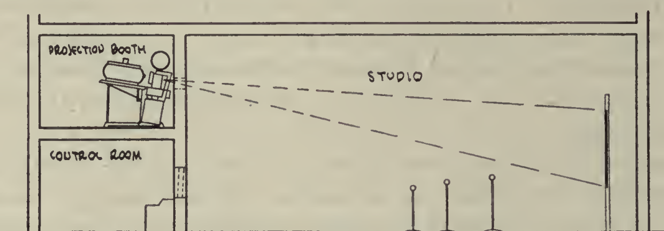

FIG. 1. Recording studio.

ment of the room be of the variable type, the walls being treated by hinged panels, one side of which is sound-absorbent and the other sound-reflectant. This arrangement permits a variety of acoustical interpretation simply by changing the position of such panels.

The actors are usually placed facing the screen and about 15 to 20 ft away from it. Three microphones are generally employed during recording. They are placed at approximately 2, 6, and 12 ft away from the actors, toward the screen, and represent the average distances at which close-ups, medium shots, and long shot sound can be re-created. These distances are by no means a "must" and will vary with each scene. The microphones will be used simultaneously or alternately, depending upon the requirements of the scene. The sound engineer may change from one microphone to another at a split second, since he has special switch-over keys at his disposal.

The actors and director work in the studio, the assistant director and the sound engineer in the control room.

We have already indicated that special equipment allowing a safe projection of film loops had to be devised. M-G-M International Films Corporation studios have developed a special loop magazine which can be adapted to any standard projection machine. Once

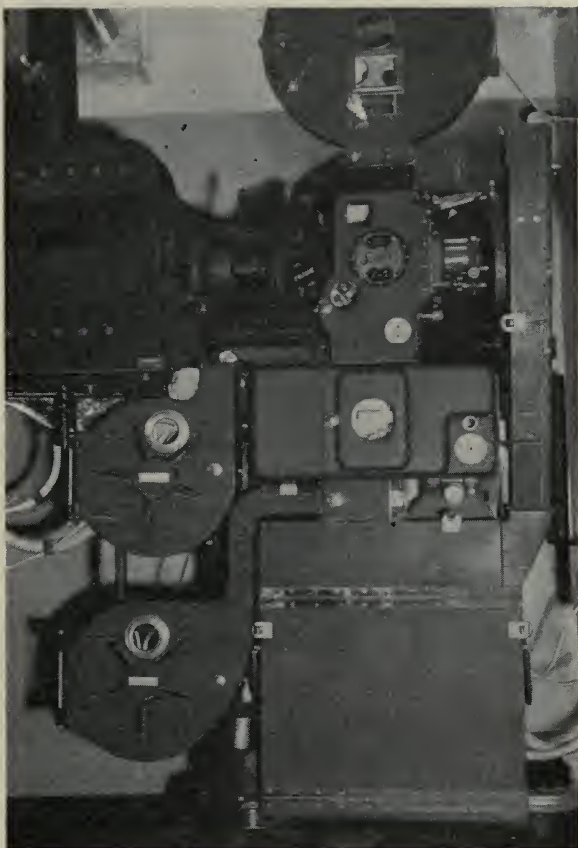

FIG. 2. Projector with special double film and loop attachment.

equipped in such manner, the standard projection machine assumes a threefold purpose. It permits the regular projection of movietone prints and also permits simultaneous projection of two films, picture and track, since it incorporates the well-known feature of the preview attachment. In addition, it permits a continuous projection of a loop.

Fig. 2 is a general view of the special loop and double film magazine in operating condition. All film is enclosed throughout its entire travel.

Fig. 3 shows the arrangement for projection of separate sound and picture. The upper left-hand magazine is sound track feed. The

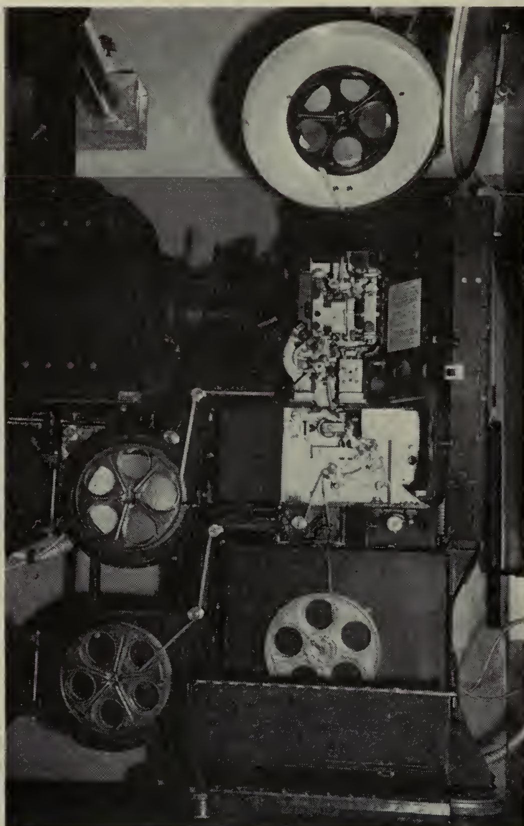

FIG. 3. Projector threaded for separate sound and picture.

lower left-hand magazine is sound track take-up. A removable spindle in the rectangular loop magazine provides picture take-up.

Fig. 4 shows the film path for the projection of separate sound and picture. Both picture and sound engage together over the projector hold-back sprocket, whereupon they follow separate paths through the sound head. The picture is kept from interfering with the track

during its passage through the sound head by the addition of four supplementary rollers. The two films engage again in the sound head hold-back sprocket, after which point they separate to their appropriate pickup magazines.

Fig. 5 shows the operating condition for loop projection. The fire trap seen at the bottom of Fig. 4 is replaced by a shoe which fits over

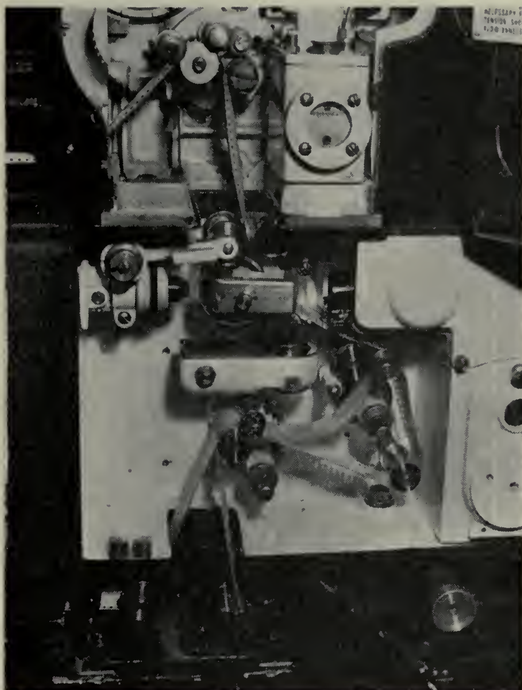

FIG. 4. Close-up of sound head threaded for separate sound and picture.

the sound head hold-back sprocket. This is needed because there is no tension on the film as it follows into the loop magazine. The spindle, required in the loop magazine when a reel is used, is removed by loosening a wing knot and a liner is inserted which reduces the width of the magazine to approximately 38 mm. The loop magazine casting must be considerably deeper than this to accommodate a standard reel. However, in order to minimize the possibility of film twisting as it lies in the loop magazine, this excess width must be eliminated and a

liner box of this sort has been found to be the quickest and easiest way to do this. The film pulls up from the bottom of the pile as seen on the right, passes over a series of rollers and enters the extension collar on top of the projector mechanism through a fire trap, from which point it follows the normal film path.

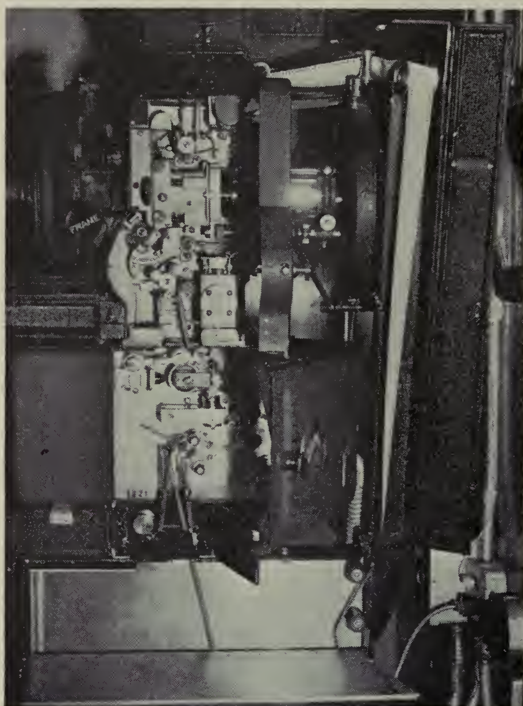

Fig. 5. Projector threaded with picture loop.

A loop is projected upon the screen, the actors watch it, and following the director's indications and guided by the sound of the voices coming from the screen, place their lines. When the general outline of the scene has been achieved, the original sound is cut off and the loop is run silent. The actors know their cues. They will now rehearse the scene for dramatic interpretation. Meanwhile, the sound engineer has placed his microphones in positions that will give him a sound record which matches exactly the action on the screen. He obtains the effect of distance at any particular spot of the scene by using different micro-

phones. If the scene starts with a medium shot and then goes over to a long shot, he will use two microphones; the first one being, let us say, 6 ft away from the actors, the second 10. At the point where the camera angle changes, the sound engineer switches "off" the first microphone and "on" the second, giving the audience the illusion of depth.

Each loop is provided with a standard leader. That leader bears a "bloop" or scratch in the sound track area and a diagonal line in the picture area that appears from the left top corner down to the right bottom corner on the screen. The purpose of the bloop is to give a synchronization reference point. The diagonal line is to warn the actors that the action will start at the moment the line reaches the bottom right-hand corner of the screen. The synchronization mark or bloop is used as follows: once the original sound of the scene has been cut off on the studio speakers, it is automatically fed to the mixing table in the sound engineer's control room. By throwing a key, the recording engineer can record that sound, but instead of recording the sound of the whole scene, he will only open his key at the time when the bloop is about to appear on the screen. The click produced by the bloop will go through the recording system and will register on the film in the recording machine, giving a reference point for lining up the new sound track with the original picture.

Obviously, there will be more than one take for each scene—on an average there are three or four such takes. It is important that each take number be properly announced and that the bloop be recorded every time.

The sound track recorded in this manner is then developed and printed in the laboratory and returned to the film editor, who in the meantime has received a copy of the director's report with all necessary instructions. Guided by the slate at the beginning of each take, the editor breaks down the sound track; he also breaks down the loops and restores them to their original form of film rolls. He will line up the synchronization mark located in the track area of the loop leader with its recorded counterpart appearing on the new sound track. He then cuts off the leaders and assembles the picture and the new sound track in its original continuity. This work is done the day after the recording session, so that at the end of the next day the production team screens the material recorded during the preceding day.

At the screening of such "dailies," the director is able to check whether the results obtained are satisfactory from the point of view

of action and interpretation. The sound engineer checks the quality of the sound and the perspective of his recording. The film editor can judge how much work there will be to synchronize properly the new dialogue with the picture.

Work of the Film Editor.—As the recording progresses, the film editor assembles more and more scenes and sound tracks, restoring the picture to its original reel form. To obtain perfect synchronism, he runs the picture and track on a moviola, advances or retards a word or a sentence, lengthening or shortening pauses between them, creating new ones, and eliminating others.

Contrary to some opinions, this is by no means a mechanical process. One must have the feeling of the word. One must have imagination in order to respace words whenever this is necessary. One must also be able to judge where the emphasis in certain sentences is supposed to fall, so that the emphasis of the sound coincides with that of the action. After the completion of the recording, the film editor will have his first cut ready. The new dialogue will be more or less in synchronism with the picture. Several screenings will take place. The director and the assistant director will indicate corrections until the production team is satisfied that the best results are achieved. At that time a final screening takes place, at which the production supervisor and two or three other directors, the editor of the script department, and eventually the writer will assist. Final corrections will be indicated, and all scenes that do not satisfy this audience will be retaken. Such retakes go through the same series of operations as the original recording, and once completed, are incorporated in the final version of the new dialogue track.

Music and Effects Tracks.—It will be necessary now to rerecord the new dialogue tracks, together with the musical background and sound effects that the original version calls for. A special music and effects track is produced. This track will contain all of the musical background and noises required by the action. The music tracks, of course, are prepared in the same fashion as they are for the original version. The sound effects are either reclaimed from those portions of the original sound track that are not covered by dialogue, or re-created. All these elements are rerecorded on the new sound track at proper levels. They are prepared in reel form to match the picture reel by reel. The dialogue track of the new version, once edited, will appear also in the same form.

Rerecording.—The new dialogue, the music, and the effects are then

rerecorded at proper relative levels to create the best possible illusion of reality. Sometimes it is necessary to have more than one dialogue track. As a rule, the singing voices are assembled on a different track to permit a greater flexibility for correction, compensation, and balance during rerecording. Sound for all special effect scenes will also be placed on a different track. At times the music or some of the sound effects are, for practical reasons, prepared in a similar manner. The total number of tracks per reel will therefore average four and sometimes as many as six or eight.

The rerecording of a synchronized version calls for exactly the same operations as those used for rerecording an original film. Such rerecording technique has been thoroughly discussed in the past and does not require any additional discussion within the framework of of our subject. However, it is extremely important to follow the basic rerecording procedure while working on a synchronized version.

The rerecorded negative is then developed in the usual manner, lined up with the picture negative, which already has the new language main and end titles and inserts, and then printed in the same manner as any other motion picture film is printed in the laboratory.

The first sample print is then screened for the production department, discussed, and if the consensus of opinion is that portions or sequences of that print are found unsatisfactory, these portions will be retaken until the final result is unanimously approved. The print is then turned over to the distributing organization, which may accept, reject, or request changes. Once the print is accepted, the picture is ready to go into the theaters and face its final test, the scrutiny of that very important person, the paying customer.

THE PAST AND FUTURE ACTIVITIES OF THE SOCIETY OF MOTION PICTURE ENGINEERS *

DONALD E. HYNDMAN** AND JOHN A. MAURER†

The Society of Motion Picture Engineers is an international engineering organization composed of a group of individuals associated in a general partnership to conduct a business, paying no salaries to officers or members, but operating on a nonmonetary principle to recommend engineering procedures; to guide, to some extent, research and development; to encourage improvement; and to lead standardization within the motion picture industry. It enjoys all the normal legal privileges of a nonprofit organization.

The Society was organized in 1916 by a group of engineers under the leadership of C. Francis Jenkins, of Washington, D. C., who became its first president. The founders of the Society had three objectives in view: (*1*) the advancement of motion picture engineering and the allied arts and sciences; (*2*) the standardization of mechanisms and practices employed in the motion picture industry; and (*3*) the dissemination of scientific knowledge through publication.

Since its organization the Society has held semiannual conventions at which engineering papers were presented and general discussion invited. These papers and discussions have been published in the TRANSACTIONS of the Society, which were issued first semiannually and later quarterly from 1916 through 1929, and in the JOURNAL, which has been published monthly since the beginning of 1930. No other source of information about the scientific and technical side of the motion picture industry is comparable in scope, in completeness, or in continuity to the accumulated TRANSACTIONS and JOURNAL of the Society of Motion Picture Engineers. The knowledge contained in these publications and in the separate reprints and reports issued

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** President, † Engineering Vice-President, Society of Motion Picture Engineers.

by the Society is of incalculable value to the industry, and represents an actual cost, for research work, of many millions of dollars.

The present membership of the Society comprises approximately 2300 engineers and technicians who are employed either directly or indirectly within the international motion picture industry and allied industries.

Because of the mutual understanding and close co-operation of these men, who know the problems in the related fields of production, distribution, and exhibition, it has been possible for the Society to bring about engineering advances that might otherwise have remained dormant for many years. These engineering advances originate in studios, research and engineering laboratories, and companies manufacturing film, equipment, and accessories. Discussion of these new techniques and products at the conventions of the Society, and publication in the JOURNAL of papers describing them, leads to their prompt acceptance by the industry, and has often resulted in major improvements in the efficiency of its operations in all departments.

When a program of continuous activity has been carried on over a period of many years, it would be an unfair misrepresentation to select certain steps in that program and say that they are outstanding accomplishments, thereby implying that the rest were routine and unimportant. A dynamo in a power plant is not less important because it emits only a steady hum instead of showers of sparks. The power and light that it furnishes are made visible in other places. Similarly, the value of the Society of Motion Picture Engineers to the motion picture industry has been in its continuous program of collecting and disseminating information, evaluating practices, recommending improved methods, and promoting standardization rather than in any isolated spectacular accomplishments, though the latter have not been lacking. The high technical quality of the motion pictures shown in theaters and the efficient operation of the equipment in studios, film exchanges, and motion picture processing laboratories all over the world give evidence that the Society has performed its functions well.

At its first meeting the Society organized four engineering committees. The names of these committees are sufficient to demonstrate the seriousness with which the Society attacked its stated objectives of advancement of the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein, and the main-

tenance of a high professional standing among its members. These four committees were (*1*) Committee on Cameras and Perforations, (*2*) Committee on Motion Picture Electrical Devices, (*3*) Committee on Motion Picture Theater Equipment, and (*4*) Committee on Optics.

From this beginning the committee work of the Society has been continuously carried on and expanded until today there are sixteen regular engineering committees on (*1*) Cinematography, (*2*) Color, (*3*) Exchange Practice, (*4*) Film Projection Practice, (*5*) Laboratory Practice, (*6*) Preservation of Film, (*7*) Process Photography, (*8*) Screen Brightness, (*9*) 16-Mm and 8-Mm Motion Pictures, (*10*) Sound, (*11*) Standards, (*12*) Studio Lighting, (*13*) Television, (*14*) Television Projection Practice, (*15*) Test Film Quality, and (*16*) Theater Engineering, Construction, and Operation. These committees have truly studied all phases of "motion picture engineering and the allied arts and sciences."

At its first meeting, in October 1916, the Society began its work of standardization by considering the dimensions of film perforations. The record shows that up to that time many difficulties in the production and editing of motion pictures had resulted from the lack of one generally recognized standard for film perforations. At the same time many prints were being damaged in projection because the dimensions of the film perforations and of the projector sprockets were not in the proper relationship. As the author of one paper on standardization expressed it, "Fellow members, upon your decisions at this and coming meetings rest the savings of untold amounts of unnecessary waste in time, money and material." Standardization of film dimensions by the SMPE caused these difficulties rapidly to disappear, and today the industry has almost forgotten that they ever existed—a most happy state of affairs.

Other fundamental problems which the Society considered at its early meetings were the principles of operation of the lens systems used in the projector and the choice of proper equipment for operating the projection arc lamp with direct instead of alternating current. A correct understanding of the lens system led to the selection of more efficient condenser lens combinations, which made possible larger and brighter pictures, suitable for larger theaters. The arc lamp was the subject of the first committee report to be published in the TRANSACTIONS, by the Committee on Electrical Devices. This report contains an admirably clear analysis of the causes of the unsteady

and flickering screen illumination often obtained with the then generally used alternating-current arcs, together with a convincing exposition of the inherent superiority of the direct-current arc lamp. This authoritative statement undoubtedly did much to speed the general adoption of the superior direct-current equipment, which gave brighter pictures free from flicker.

Another important activity which began in the first year of the Society's existence was the creation of an accurately defined motion picture nomenclature. This work has been carried forward continuously by the Committee on Standards and Nomenclature (known today simply as the Committee on Standards) and is being promoted actively at the present time. Commonly accepted terms and definitions avoid confusion, dispute, and waste.

Any reasonably adequate review of the work done by the SMPE during the 30 years of its existence would require a book rather than a brief account such as is being given here. The indexes alone, covering the engineering papers and committee reports published in the TRANSACTIONS and JOURNAL, fill 369 pages of small type. Reports by engineering committees, not counting the reports of the Historical Committee and the Progress Committee, totaled 244. These figures give impressive evidence of the continuity of the Society's work and of its success in stimulating research and the exchange of engineering information. They fail to show the thoroughness with which all phases of motion picture technique have been studied by the authors and committees represented. The work of the Society has been a perpetual backlog of valuable information on which industry success has been built.

Many of these committee publications concerned standards. Collected editions of standards were published in 1920, 1928, 1930, 1934, 1938, 1941, 1944, and will be published again this year, 1946. The standards adopted by the Society have been recognized and followed by manufacturers all over the world. They eventually became official American Standards, and today they provide a secure basis for international standardization of all dimensions pertaining to motion picture film and the machinery used with it.

An outstanding accomplishment of the Society was the preparation, by the Committee on Projection Practice, of comprehensive plans and safety specifications for projection rooms in theaters. These plans have been followed in the great majority of theaters constructed since they were first published in 1931, and they have

been officially recognized by being incorporated in the building codes of several states, including the State of New York. The advantage of having reasonable and practical safety standards thus formulated by the motion picture industry itself, instead of having them imposed by less well-informed outside authorities, hardly needs to be emphasized.

Since the formation of the Research Council of the Academy of Motion Picture Arts and Sciences in 1934, the SMPE has at all times co-operated with the Research Council to the fullest extent, as it did, for example, in adopting and publishing the Academy's Standard Electrical Characteristics for Theater Sound Reproducing Systems. It has kept the Research Council informed of the engineering work being carried on by its committees, and has sought the advice of the Council on all projects of motion picture standardization. The Society and the Research Council look forward to increasingly close co-operation in the immediate future, when both will be studying the engineering and industrial problems of television and its relation to the motion picture industry.

As good a criterion as any of the strength of an organization is its ability to meet emergencies and deal with them successfully. Several times in recent years the Society of Motion Picture Engineers has met and passed this test. In 1935 a serious problem arose when the German standardizing body adopted a set of standards of 16-mm sound film which would have made their projectors and film noninterchangeable with those made in America. During that year and 1936, the SMPE steadily sought to achieve world standardization in this then comparatively new industry. These efforts were supported by Great Britain which, early in 1936, adopted the SMPE standards for 16-mm sound film. Representatives of the SMPE were sent to Europe, and by the end of 1936 full international standardization was achieved, involving only one minor change from the earlier SMPE standards.

A more comprehensive test was presented in the latter part of 1943 when representatives of the Armed Forces requested the SMPE to undertake an extensive program of war standardization. First the Standards Committee and then the Board of Governors of the Society gave prompt consideration to this request, and the Engineering Vice-President, who has general charge of all engineering committees, was authorized to proceed with the necessary work of organization. It was decided that the work should be carried on directly under the

auspices of the American Standards Association, but that the personnel of the committees on motion pictures should be supplied by the SMPE and by the Research Council of the Academy. The subcommittees thus organized to work with the War Committee on Photography and Cinematography Z52, of the ASA, began their work promptly and within six months had completed the major tasks assigned to them. These included the development of specifications for 16-mm Sound Motion Picture Projectors especially suited to the needs of the Armed Services, a specification for 16-mm Motion Picture Release Prints, Methods of Determining Resolving Power of Lenses, and specifications for eight test films for checking and measuring the performance of 16-mm projectors.

Later work by these committees included specifications and dimensions for screens, for 16-mm projector reels, specifications for tests required for quality control, standardization of sound records and scanning area for 35-mm sound motion picture release prints, and standardization of synchronization marks for release print negatives. Many of the Society's members have also served on other committees which have arrived at war standards for the field of still photography.

It is important to note that the rapid rate of progress in this war standardization work resulted from the fact that most of the problems presented were closely related to ones that had been studied by the committees of the SMPE. For example, Subcommittee *D* of the War Standards Committee, which prepared specifications for the Service Model 16-Mm Sound Projector, was able to begin its work with a draft based on specifications for projectors for educational use contained in a report of the Committee on Nontheatrical Equipment published only two years earlier, and this material was found to be so complete that only three meetings of the war standardization subcommittee were necessary to arrive at a satisfactory specification. Similarly the specifications for lens testing and for test films were based on previous studies by the Society. No organization which participated in any of the several war standardization programs initiated by the Army and Navy has more right to be proud of the promptness with which it was able to meet the needs of the Armed Services.

An important aspect of this wartime work is that it forms a basis for new peacetime standards and specifications of great value to the industry.

A more recent example of the ability of the Society to act in an emergency is the part it has played in securing frequency allocations by the Federal Communications Commission of the United States Government for the needs of theater television. When the Television Committee of the Society of Motion Picture Engineers, at its meeting on September 18, 1944, studied the recommendations of the Radio Technical Planning Board on frequency allocations for experimental television, it was considered that these recommendations did not explicitly incorporate the needs of the motion picture industry. It was decided that the Committee should take steps to insure adequate protection of the future requirements of theater television by making specific requests for the necessary channels at the Federal Communications Commission hearings in October 1944.

Accordingly, a delegate was appointed by the Committee to present the frequency allocation needs of theater television before the Commission.

Later in the hearings before the Federal Communications Commission, the Columbia Broadcasting System, Inc. filed a brief in part of which it opposed the granting of frequency allocations for theater television. The Society, through its representative, Paul J. Larsen, promptly presented a rebuttal which must be judged to have been effective, inasmuch as the Commission on May 25, 1945, issued a report in which it granted substantially the allocations requested by the Society. Thus the alertness and energetic action of the SMPE have safeguarded an opportunity for what is likely to prove to be a major development in the motion picture theater field. Not stopping with this, however, the Society has begun to work for the realization of this important development by setting up a new committee, the Committee on Television Projection Practice, to study the special problems of installing and operating television equipment in the theater. As usual, the Society remains in the forefront of progress.

Earlier in this paper an example was given of how the standardizing activities of the SMPE eliminated waste in the production and exhibition of motion pictures. Lack of space made it necessary to omit mention of many other instances of this kind, among which a a series of committee reports on wartime conservation is noteworthy. One such activity that is going on at the present time will be described because it illustrates the importance of services that the Society is continually rendering to the motion picture industry.

It has been known to a number of engineers for several years that improved characteristics of the film stock being manufactured today make possible a more nearly ideal choice of the diameter of the intermittent sprocket of a theater projector than the diameter which has been in general use.. Projector manufacturers and theaters have been reluctant to make such a change, however, until the facts were proved by a sufficiently long series of practical tests.

Accordingly, in 1943 the Standards Committee of the Society set up a Subcommittee on 35-Mm Projector Intermittent Sprockets, and this Subcommittee arranged to carry out a comprehensive series of practical tests with sprockets of different diameters in theaters in New York City and in Rochester, N. Y. A report on these tests was presented at the 57th Semiannual Technical Conference of the SMPE in Hollywood, California, on May 16, 1945. This report showed that no trouble was experienced with the larger sprockets, while it was proved that a general change from the currently used diameter of 0.935 in. to the recommended diameter of 0.943 in. would double the number of projection runs obtainable with any given release print. The Society has proposed to the American Standards Association that this new diameter (0.943 in.) be adopted as an American Standard, and is taking steps to give proper publicity to the results of its tests so that the entire industry may be made aware of this opportunity to conserve film.

Nonengineering Activities of SMPE Committees.—Much work of importance to the motion picture industry is accomplished by nonengineering committees and groups of the Society. There are some 14 such committees, among which the Papers Committee is outstanding. This committee is responsible for obtaining material on engineering developments in the industry for presentation at the conventions of the Society. The Technical News Committee gathers items of current interest to the industry for publication in the JOURNAL. The Historical and Museum Committee collects and assembles data on early motion picture equipment.

The technical achievements of industry pioneers are reviewed and considered by the Progress Medal Award Committee, and those deemed worthy of such recognition are awarded the Society's gold medal.

These and many other nontechnical groups within the Society contribute in large measure to the technical literature made available to the industry and to the public.

Journal.—Perhaps of greatest importance to the industry is the Journal of the Society which is published monthly. Over 2500 papers, exclusive of committee reports, have been published in the Journal on standardization and other industry engineering subjects.

The contents of the Journal have been referred to and praised by leading engineers and technicians throughout the world, who regard it as the only complete source for motion picture knowledge.

The Society also publishes booklets on standardization, committee reports, and recommended procedures.

Engineering Conventions.—Since 1916 the Society has held 59 conventions attended by engineers, technicians, executives, and other representatives of the motion picture and allied industries. These semiannual meetings give opportunity for members to exchange new developments and to discuss processes and equipment used by the industry. Papers are presented which are later published in the Journal. By attendance at these group discussions industry representatives are kept informed on subjects of mutual benefit.

Regional Sections.—Between general engineering conventions, monthly meetings are held by the Atlantic Coast Section in New York, the Midwest Section in Chicago, and the Pacific Coast Section in Hollywood, at which similar discussions of industry engineering subjects are conducted. Thus, the motion picture engineer has frequent opportunities to exchange views and obtain information on problems confronting him.

Engineering Information Service.—The Society is continually called upon to supply engineering and technical information to all branches of the motion picture industry. Letters, telephone calls, and telegrams are received from studios, exchange branches, and theater circuits requesting data on a wide variety of subjects. Although the Society cannot at present meet all demands for such information because of insufficient facilities, it has contributed (as far as possible) in the general distribution of engineering knowledge for the mutual benefit of the entire industry.

Proposed Projects.—For several years it has been apparent to the Board of Governors and Officers of the SMPE that certain activities ought to be undertaken and others carried on at an accelerated rate in order to meet properly the present and future needs of the motion picture industry. Much of this additional work could not be undertaken in the past because sufficient finances and adequate personnel were not available.

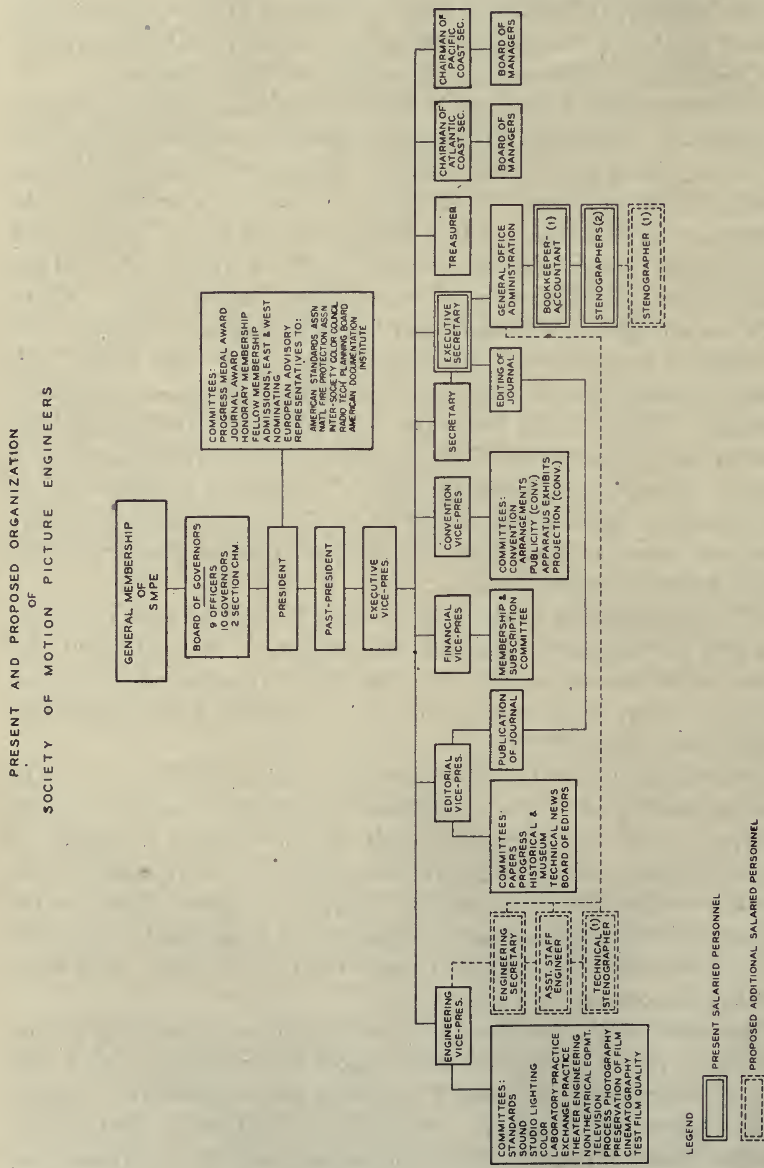
With additional financing now available and with an increased secretarial staff, the SMPE is now carrying on group engineering at a much accelerated rate on problems and projects related to production, distribution, exhibition, films, equipment, and accessories.

It also has under way the most ambitious standardization program in its history. Virtually all the motion picture standards in existence before the war as well as the numerous emergency standards adopted during the war have been or are being reviewed by a number of subcommittees of the Standards Committee, and many useful facts have already become apparent as a result of this study. Many standards, of course, have been found entirely satisfactory. Others, while not changed in substance, have been improved in accuracy and clearness of presentation. In some cases it has been found that changed conditions in the industry make definite changes in standards desirable. In still other cases the need for better techniques than those known at present has been revealed by this searching study. A number of important technical papers, discussing problems which have come to light in the course of this review of motion picture standards, are to be presented at coming meetings of the Society and will be published in the JOURNAL.

All standardization work of the Society is done in close co-operation with the American Standards Association. The Sectional Committee on Motion Pictures Z22, of the ASA, is sponsored by the Society, and many of its members are also members of the Committee on Standards of the SMPE.

Detailed studies of the inter-relations of the television art and the entertainment field of motion pictures have been under way for the past year. This work involves such specific projects as studies of frequency allocation and bandwidth requirements of television in relation to screen definition, private addressee systems, study of the problems of installing and operating television equipment in theaters, and correlation of the technical terms used in television with those used in photographic technology.

Past issues of the JOURNAL and TRANSACTIONS of the Society contain many papers of fundamental importance relating to such subjects as cinematography, sound recording and reproduction, motion picture laboratory practice, the optics of projection systems, *etc.* The usefulness of much of this information, however, is impaired because of the lack of correlation of the work of the various authors and because some of the material is out of date. One of the most im-


PRESENT AND PROPOSED ORGANIZATION
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PROCESS PHOTOGRAPHY
PRESERVATION OF FILM
CINEMATOGRAPHY
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FIG. 1.

portant projects being undertaken by the Society is the correlating, assembling, editing, and preparation of original material where needed for engineering reference books and reports on the above mentioned subjects and on film exchange practice, motion picture process photography, motion picture theater engineering, preservation of

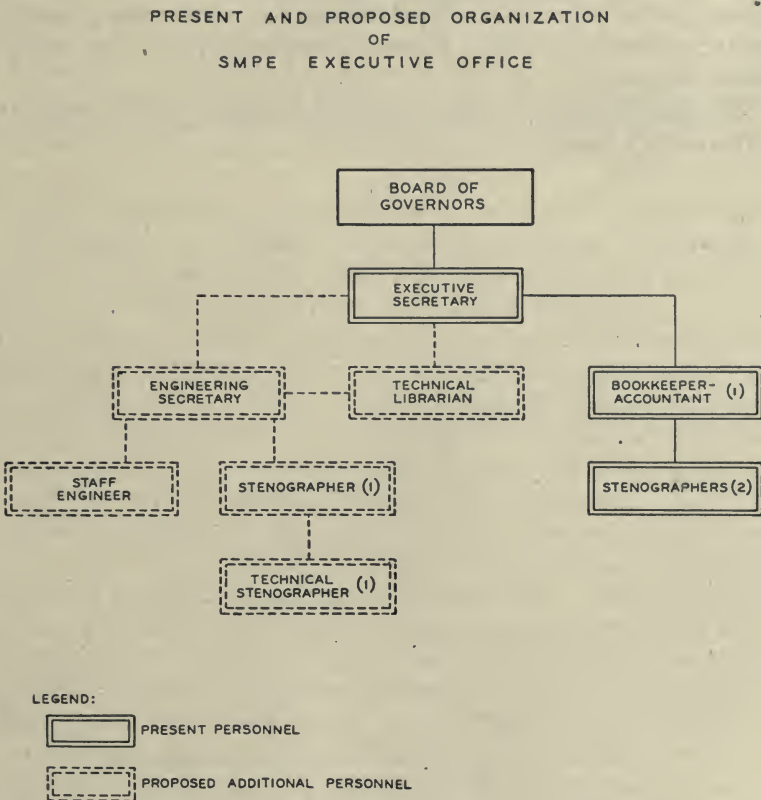

FIG. 2.

film, and for a motion picture projectionist's handbook. These books are urgently needed not only in the industry but also as text books for the teaching of courses on motion pictures in colleges and universities. Such courses are now proposed in answer to numerous requests from members of the Armed Forces as well as from civilians who, in past years, have often asked the Society to recommend in-

stitutions giving courses in motion picture production, distribution, and exhibition.

Performing these tasks with an adequately staffed executive office the Society, in co-operation with the Research Council of the Academy of Motion Picture Arts and Sciences, will be able to bring about improvement in engineering practices that will increase economy, advance public relations, increase the entertainment value of motion picture productions, and in general raise the stature of the motion picture industry.

The organizational increases required to carry out this work are shown in Figs. 1 and 2.

MODERNIZATION DESIRES OF A MAJOR STUDIO*

LOREN L. RYDER**

Summary.—*This paper is a discussion of technical things to be accomplished if motion pictures are to remain the best form of entertainment presentation at competitive cost. It includes ways and means of better utilizing the developments of World War II, also suggested usages of some of these developments.*

Most of the articles in the JOURNAL of the Society of Motion Picture Engineers are technical discussions of things accomplished. This is a discussion of things still to be accomplished. It is a statement of the problems facing Hollywood and the industry.

In the future as in the past the success of motion pictures is dependent upon retaining the best form of entertainment presentation at competitive cost. The motion picture industry has enjoyed lavish prosperity hinged largely on a technique—a mechanical means of presentation. The same writers, directors, producers, and actors have found no equivalent means of entertainment expression.

We have arrived at the present state of the art through two phases—first, silent and, then, sound pictures. Sound in pictures along with radio was a derivative of World War I. We are just beginning to feel the impact of the vast developments of World War II. The objective of this paper is to stimulate thinking and aid in bringing into this industry those developments and devices which have application to 35-mm motion picture work. The same thinking and exchange of ideas will aid television and 16-mm production.

It must be kept in mind that the studios are manufacturers of entertainment and not designers or manufacturers of equipment and materials. Most of the development work in the studios is done within individual departments to meet specific problems in production or showmanship. The effort in this regard is properly directed and will no doubt continue in the industry. On the other hand the extension of this noncentralized engineering practice has and is resulting in an increasing divergence in the industry equipment and methods. It is

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* Presented May 9, 1946, at the Technical Conference in New York.

** Director of Recording, Paramount Pictures, Inc., Hollywood.

cumbersome and costly. It is of necessity short-range thinking; it is a deterrent to legitimate manufacturers.

In the past most of the worth-while basic research and much of the applied engineering for this industry has been done by the manufacturers. It has been profitable to manufacturer and consumer alike. The lack of a new horizon and a war have slowed down progress to incremental improvements. If this industry is to advance with the trend of the times, both supplier and consumer must discuss the problems and requirements until there is general understanding.

Development activity in the motion picture industry may be considered under three main headings: to accomplish new effects in showmanship; to obtain improved technical quality; and to achieve economy. Most projects are directed at one of these objectives with little regard for the other two.

As indicated earlier most development activity on the part of the studios is directed toward showmanship. The studios are endeavoring to make more real and more spectacular a fiction story. War experience with stereoscopic gun trainers in a hemisphere or planetarium-type dome was certainly more real and effective to the trainee than a flat screen. Perhaps the theater of tomorrow should be a planetarium in which the audience sees everything and hears everything in normal surroundings as in real life. Possibly a sector of a sphere of grandeur size will accomplish the desired effect. War developments in optics have exceeded our fondest expectations. Will it be possible to produce a picture equally satisfactory from the front, middle, and rear seats of a theater? How can we obtain stereoscopy? Twentieth Century-Fox has made a test demonstration of 50-mm color film on a large screen backed by stereophonic sound. Some people feel that theater sound reproduction would be enhanced by either a two-speaker system or stereophonic sound. Others feel that sound to match stereoscopy will have to be truly three-dimensional rather than subjective from three horns. We all know that we need more color.

Progress during World War II was made by men who refused to be restricted by the limitations of the present. The same approach should be used in the present thinking, after which the decisions can be tempered by economics and good business.

Quality improvement has received more industry-wide attention than either showmanship or economics. It is a more obvious need to the technician. It is usually more direct to accomplish and is imme-

diately satisfying when accomplished. Unfortunately quality improvements do not pay in the box office in a manner comparable to improvements in showmanship, nor do they pay on the balance sheet comparable with economy.

Economy is most evasive. The studios are very cost conscious but the answer is not quite clear. Most industries compete on a cost basis. A few compete on a quality basis. In picture work the competition is in showmanship and entertainment. Cost is something that seems to affect the final balance sheet, making it red or black. In an effort to gain showmanship the industry has gone through a period of "gadgeteering" almost without reference to operating costs and without unification. As compared to cost-competitive manufacturers, motion picture making is obsolete, old-fashioned, and inefficient. The individualism of showmanship is carried into the mechanics of production. Everything is still done by force of manpower. This is not a plea for fewer men but for better tools and devices for the men to use. Production time is the major cost item in 35-mm production, 16-mm production, and television. With old and obsolete equipment in the field, now is the time to plan the unification and modernization of the equipment and materials required for these three great industries. Equipment effecting real economy may prove to be first in demand.

The following is a discussion of certain activities which may have application to motion picture making.

Lighting.—In the field of lighting it has been stated that the presently used 120-v potential was arrived at as being the highest voltage which could conveniently be taken in shock by a man and therefore may not be the most effective and efficient voltage for gaining illumination. Likewise, the present 60-cycle frequency is merely a marginal improvement over the old 25-, 40-, and 50-cycle frequencies which are even yet being abandoned. A 400-cycle supply has become standard for aircraft and much of the Army and Navy equipment both on shore and the sea. At this frequency transformation is simple and the desired voltage can always be available at the point of usage. It may be that the industry should make a long-range review of this situation. Some of the lights now being developed may operate more effectively and without flicker at this higher frequency. This includes such lamps as the discharge lamp, the high-intensity fluorescents, the incandescents of either the standard type or low voltage high-amperage type such as were developed

for signaling and aircraft landing. Other lamps which show promise are the zirconium lamp and mercury arc. It is also hoped that something can be done to our "inkies" and arcs to make them lighter in weight, more convenient and more effective. Work is in progress in an effort to increase arc illumination for background projection.

Back-lot shooting areas should be enclosed because of shadow trouble and sound interference from airplanes. This cannot be done because there is not enough lighting equipment in Hollywood, excluding the sun, to light an entire street for Technicolor shooting. There is a need for some type of general lighting for large fixed sets and backings.

Photography.—In an effort to gain greater utility with the camera some of the studios are already developing gyro-stabilization with servo-control in a manner similar to that used for gun pointing. This stabilization will be most effective on dolly, camera boom, and camera car shots. It may also eliminate the costly present practice of building tracks and special roadways for such shots. The same type of servo-control mechanisms will be used to gain repetition of mechanical movement during the picture shooting and during special effects work. It can be used to time foreground action to background projection.

Thirty-five millimeter cameras are too large, too heavy, too noisy, and too covered with gadgets. One Paramount camera was noted to have 19 gadgets associated with it.

The increase in film speed which has been accomplished is sincerely appreciated but the industry could use to advantage still faster films and lenses. The improved image orthicon now available to television may point the way to a higher speed, lighter, and noiseless camera with a picture recorder operating off-stage in a manner similar to sound recording. The light amplifier demonstrated by Dr. Zworykin may have application to existing types of cameras and lenses.

Sound.—The writer's desire in regard to sound equipment includes: a microphone, directional at low frequencies and relatively nondirectional at high frequencies, preferably weighing not more than one or two pounds; a microphone boom capable of changing the angle of the microphone as well as rotation, plus all of the normal movements—this microphone boom and the cables associated with it should cast the minimum shadow and, if possible, soft shadow lines; a mixer unit about the size of a large book; an amplifier and recorder mounted in a suitcase or on a lightweight dolly; and a motor system

with motors the size of aircraft motors, also free from all the complexities and inefficiencies of our present motor systems.

Set Construction.—The system of set construction, like the fabrication of houses, has not been modernized in years. The theatrical business needs a completely new expendable material for set construction, for example, a material which may be put together in a manner similar to carton construction and abandoned after picture shooting.

The industry needs fast-drying paints, especially paints with high gloss that can be sprayed on floors between takes to retain the mirror-like flawless effect which is so spectacular in reviews and dance numbers.

The industry needs new carry-alls for set handling and cranes or elevators for overhead rigging.

Plastics.—New plastics, plywood, adhesives, and glass products should all find their way into motion picture making.

It is the writer's hope that in the immediate future it will be possible for the industry to give the manufacturers a more complete and satisfactory statement of the requirements which should make manufacturing more certain, more profitable, and more modern.

DUBBING AND POST-SYNCHRONIZATION STUDIOS*

WILLIAM A. MUELLER**

Summary.—*The paper covers design and operating considerations for two foreign-dubbing and post-synchronization studios recently built on top of the Music Building of the Warner Brothers lot in Hollywood, California. After describing constructional details to provide satisfactory acoustical conditions in the rooms, the paper concerns itself with the technique of adding foreign dialogue to completed pictures and dubbing in replacement lines to photographed sequences which, originally, were too noisy to permit the recording of intelligible speech.*

Before the war the dubbing of foreign dialogue into American pictures was done in the countries in which the picture was released. As a result of the war, this work necessarily had to be transferred to the United States and at Warner Brothers we were required to dub a number of Spanish, French, and Italian versions of domestic releases; work which had been previously done in Madrid, Paris, and Rome.

When this program was first started, a review room was equipped for this purpose, but shortly thereafter the project assumed such size that it was necessary to build special recording stages to handle the work.

Inasmuch as foreign dubbing was a temporary wartime adjunct of our normal operation, the rooms were to be designed to serve equally well as studio review rooms or narration recording studios. Fig. 1 shows a plan view of two recording studios built specifically for foreign dubbing with these specifications in mind. As may be noted, the projection room is located between the two recording studios, so that the projection and sound equipment is centralized, and maintenance and operation problems are simplified. This also reduces film handling, as the rooms were built ont he second floor of another building, and an elevator was provided to carry filmd irectly from the street into the projection room.

The rooms are 61 ft long, 35 ft 5 in. wide, and 18 ft high, giving a

* Presented May 9, 1946, at the Technical Conference in New York.

** Warner Bros. Pictures, Inc., Burbank, Calif.

dimension ratio of approximately 3:2:1, which is in the optimum range for rooms of this size. This ratio assumes that the length of the room is measured to the front of the screen, since the space behind the screen is separated from the room by a heavy drape and cannot be considered as part of the main enclosure.

In considering the acoustic design, it was desired to use nonparallel walls, reducing room width toward the front or screen end, which not only results in good acoustics but also good motion picture presentation and design, as the audience interest is focused toward the screen. However, wartime material restrictions prevented this, as splayed and nonparallel surfaces called for double walls and doubled the

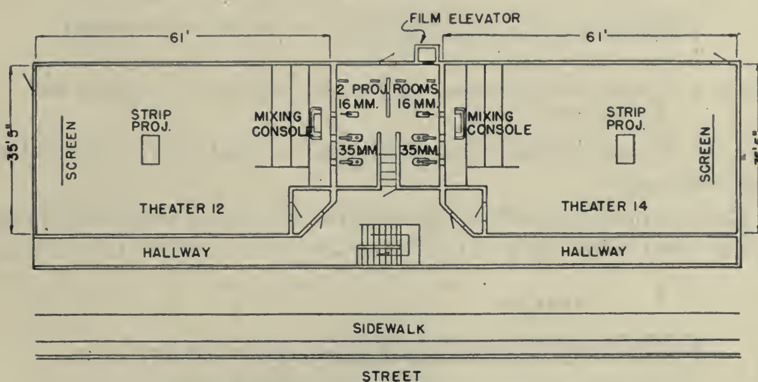

FIG. 1. Plan view of recording studios.

quantity of strategic materials required but not available. An older method of acoustic design was therefore resorted to, using alternate reflecting and absorbing surfaces, with a reflecting surface facing an absorbing surface on the opposite side of the room. The rear wall of the room was entirely covered with a sound-absorbing material, having a uniform characteristic with respect to frequency. The entire ceiling was surfaced with hard plaster and the floor covered with carpeting. The floor was terraced toward the rear wall, which is very desirable from an audience viewing standpoint and extremely important acoustically as it tends to increase sound diffusion in the room.

The rooms were adjacent to a public street adjoining the studio, so that considerable attention was given to the matter of noise insulation. Noise measurements on this street showed a maximum noise level of +74 db referred to 10^{-16} w when using a 70-db weighting net-

work. Our previous experience indicated that a maximum room noise level of about +30 db, using a 40-db weighting network, was neces-

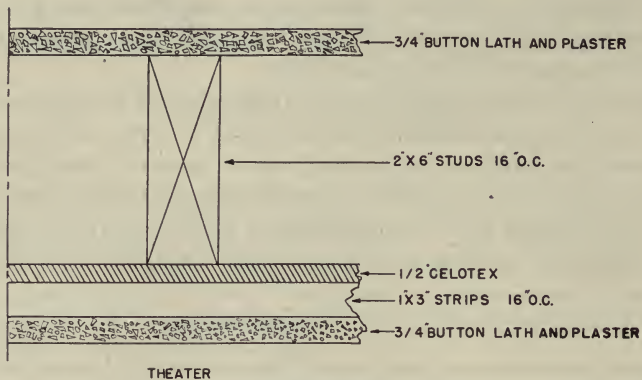

FIG. 2. Detail of walls between theaters and hallways and exterior walls.

sary for satisfactory recording conditions, so that 45 db of insulation was indicated.

This was obtained, first, by placing the corridor of the building next to the street, which helped to isolate the rooms, and, next, by using a

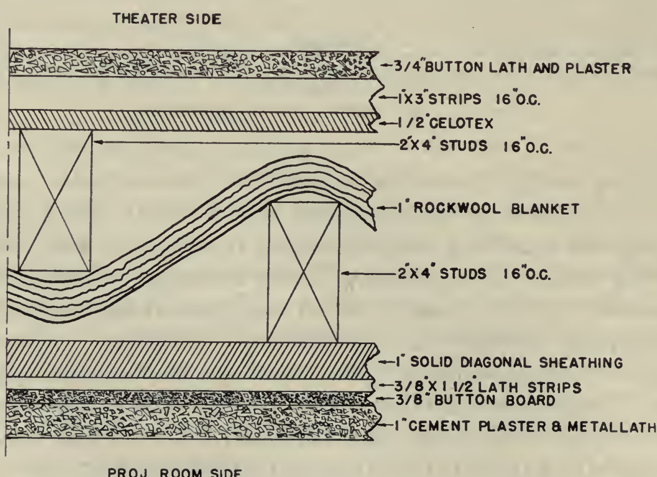

FIG. 3. Detail of wall between projection rooms and theaters.

laminated wall construction with interior dead-air spaces, as shown on Fig. 2.

The insulation of the projection room wall was also important, as the projectors have a high normal noise level and must be adequately insulated from the recording studios. This partition is of the double wall construction, as shown in Fig. 3, and as a further precaution, the noise level at the source was reduced by treating the upper parts of the walls and ceiling of the projection room with a fireproof absorbent. The air-conditioning system was provided with acoustic baffles at the inlets and outlets to eliminate noises coming through these openings,

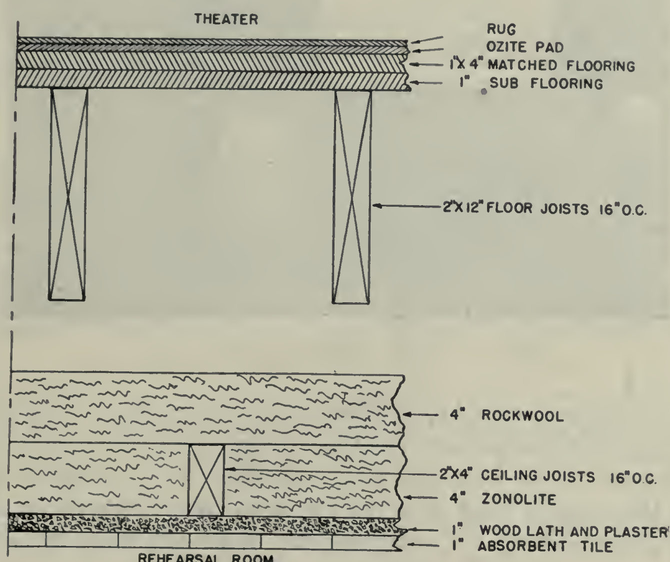

FIG. 4. Detail of theater floor construction.

and a low air velocity was employed to reduce noise caused by air flow.

These rooms were constructed by adding a second floor to the present single story music building in which were housed several vocal rehearsal rooms. It was held essential that the different working units should be able to operate simultaneously without noise interference, and the ceiling and floor construction shown in Fig. 4 provides sufficient insulation between the rooms to achieve this end.

All of these precautions in design and construction have resulted in a room (Fig. 5) which is excellent for recording from the standpoints of noise level and sound quality. The actual noise level of the room is

+32 db, using a 40-db weighting network while the projection machine and strip projector are in normal operation.

Since the rooms were designed to serve as review rooms when not needed as foreign dubbing rooms, a special motor system was pro-

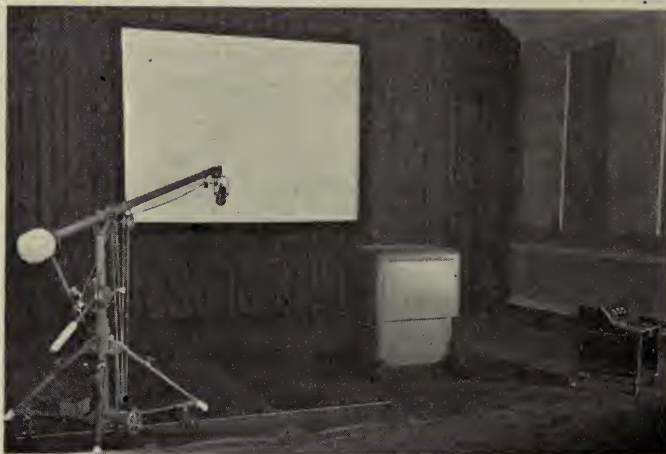

FIG. 5. Screen end of recording studio.

vided, a schematic drawing of which is shown on Fig. 6. As will be noted from the illustration, one of the projectors is driven either by a synchronous or an interlock motor mounted on a common shaft. When the room is used as a review room, the synchronous motor drives the projector in the usual fashion. When it is used as a foreign

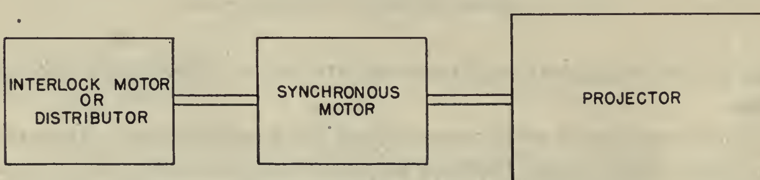

FIG. 6. Projector drive.

dubbing stage, the interlock motor drives the projector in synchronism with a dialogue strip projector and recording machine during takes. For rehearsals, the synchronous motor drives its associated interlock motor as a distributor, and this distributor, in turn, drives the interlock motor on the strip projector. This is a greatly simpli-

fied form of the motor systems previously used and has proved very efficient and time saving for operations of this nature.

It was found, in dubbing foreign languages into American pictures, that the best means of cueing the actors was visual. Not only was it necessary for them to see the picture of the scene to be dubbed, but it was also found best to supply them with a visual projection of the dialogue, written in the foreign language. A special strip projector was used to project this dialogue, as well as a synchronizing mark, on the screen underneath the picture.

In practice, a scene in foreign dubbing is made as follows:

The picture is divided into short sequences, and the sequences are projected with the American dialogue once or twice for the actors to get the feeling of the scene. The loudspeakers are then turned off and rehearsals made, projecting the picture, and the foreign dialogue beneath it, on the screen. When rehearsals indicate satisfactory performance, a take is made. Usually, several takes are necessary in order to get proper synchronization throughout the entire scene, and, at times, parts of several takes are used to complete a more perfect one.

With the end of the war, foreign dubbing in the United States stopped and was returned to the countries in which the films were to be released. These rooms are now being used for recording of narration and post-synchronization of dialogue for our American releases.

The shooting of exterior scenes in all the Hollywood studios has become more and more troublesome, owing to the tremendous number of takes that are spoiled by airplanes. On Saturdays, when the traffic is heaviest, it is very difficult to shoot outdoors. The Sound Department of this studio has surmounted this difficulty by the technique of post-synchronization; that is, the sound track which has been recorded on the set, and was spoiled by extraneous noises, is used as a cue track, and the actors are taken into our post-synchronization stages and new dialogue is recorded to correspond with this cue track. It has been found that some of the techniques developed for foreign version synchronization are useful in post-synchronizing domestic releases. Many actors respond better to visual dialogue cues than to the audible dialogue played back for them through a headphone. Others work much better with a combination of visual and audible cues.

In post-synchronizing sound pictures, it is very important that the mood, feeling, and dramatics of the scene be preserved as they were recorded originally. Every effort is made to preserve these characteristics, and it is especially important that the acoustics and pickup

quality of the post-synchronized scene match exactly the scenes which precede or follow it. This is essential, since any change in acoustics, or acoustic perspective, betrays to the listener that the scene is a "phoney." For this reason, these rooms are equipped with every facility for changing the acoustics to match those of the sets being projected on the screen.

Fig. 7 shows the room in operation and particularly the adjustable panels which are used to control the acoustics of the space surround-

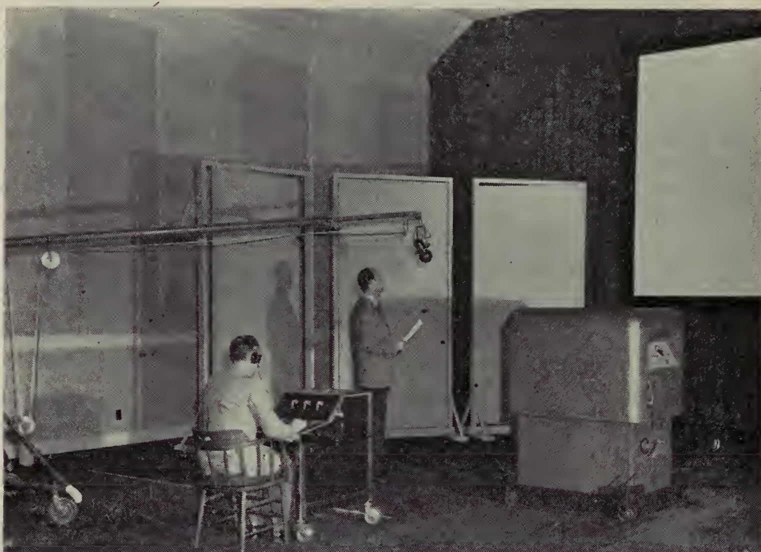

FIG. 7 A typical post-synchronizing setup.

ing the actor. They are surfaced on one side with a soft absorbent, and on the other side with a hard reflecting material, and the side which best simulates the set conditions is used. In addition, the nature of the floor can be changed from a rug-covered, or carpeted type, to a hard-surfaced floor, such as linoleum or wood. With this equipment, it is possible to match the acoustics of practically any type of scene encountered in normal picture production.

In order to supply proper realism to a scene being post-synchronized, it has been found that the actors must make the movements which they are shown making on the screen. They absolutely must not stand still in front of the microphone and read their lines. For

instance, if the scene shows an actor seated for a portion of the scene and then rising to deliver the remainder of his lines, this action must be repeated in post-synchronization, as there is sufficient difference in the voice of a person when seated and standing to cause an unnaturalness in the recording. Also, the jarring effect, caused by walking, creates a modulation of the voice that must be duplicated by the actor by walking as he did when he was photographed. The actor must walk into a scene, out of it, or toward the microphone in post-synchronization, just as he did in the actual scene, if true realism is to be achieved. If a person is shown in bed, it is impossible to match the sound track except by having the actor lie down, and the correct handling of countless details such as these is necessary to achieve a natural duplication of the original scene.

The technique of post-synchronization has achieved considerable savings in motion picture production in Hollywood. By its use, pictures may be "shot" on locations that were previously too noisy to secure intelligible dialogue, and photographic effects, such as wind, rain, or lightning, can be used at an intensity which would previously have ruined the dialogue.

In one of our recent pictures, *A Stolen Life*, much of the action took place in a small lighthouse, located on a rocky peninsula jutting out into the ocean. This rock became an island at high tide, and the noise of the waves and surf was so loud as to make the dialogue unintelligible. Photography at the location was ideal, and by post-synchronizing the dialogue, a much more satisfactory result was secured, at lower cost, than would previously have been possible.

In another production, there was a scene showing the principals ice skating on a small woodland pond. The cost of providing a refrigerated surface, so that ice skates could be used, was too great, so roller skates were substituted, which, naurally, were extremely noisy on the hard floor. The scene was photographed so that it was not apparent that the principals were not on ice skates, and the noise was eliminated for this sequence alone.

In conclusion, it may be stated that actors, directors, and producers have shown an enthusiasm, totally unexpected, for the facilities thus provided for extending the application of sound recording to their art.

The author wishes to thank Michael Rettinger, of RCA, for his assistance in the acoustic design of these rooms and Thomas Sharpe of the same company for his suggestions on the described motor system.

THE RELATION OF TELEVISION TO MOTION PICTURES*

ALLEN B. DU MONT**

Summary.—*This paper describes how these two picture-reproducing techniques can work together with growing advantages to both, rather than engaging in bitter rivalry as erroneously anticipated.*

It is altogether natural that a new art should be viewed with some suspicion by the older art. The actual scope of the newcomer is a matter for speculation. There is no telling at first how great or how small that scope may be. But in the vast majority of cases the new art soon fits into its own well-defined groove, serving a heretofore unserved need. As often as not the new art eventually supplements, rather than replaces, the older art, thereby rounding out the over-all services to the public. So what were erroneously regarded as bitter rivals are ultimately drawn into a workable partnership as mutual advantages become increasingly apparent and real.

Your motion picture industry is a case in point. When movies progressed from the level of scientific curiosity, or side show, to that of the crude entertainment of the nickelodeon, or poor man's theater, there were some misgivings among theatrical folks. Such misgivings gave way to genuine apprehension and even strong opposition when producers of the first full-length photoplays put in bids for topflight stage stars. And when talkies gave voice to the screen, with natural color thrown in for good measure, the legitimate stage really had something to worry about.

However, the movies that seemed such a serious threat at first to the general welfare of the legitimate stage have in time fitted into their own particular groove. The recorded or canned show now parallels that of the time-honored stage. There is little direct conflict. Rather, there is close co-operation today. Actors perform for the stage, and then for the movies, and back again to the stage; the

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* Presented Mar. 13, 1946, at a meeting of the Atlantic Coast Section of the Society in New York.

** Allen B. Du Mont Laboratories Inc., Passaic, N. J.

better for their broadened experience. Movies have their place. The legitimate stage has its place. Folks go to see the movie version and then insist on seeing the stage version. Both can be delightfully different. Actually, the movies are feeders for the theaters. Theater receipts were never greater. And so the legitimate stage has found it profitable to supply the movies with performers, writers, and best plays. There is no longer the slightest fear of one putting the other out of business.

History is about to repeat itself with the advent of commercialized television. However apprehensive the motion picture industry may have been with regard to television, such doubts have given way to growing interest and a closer collaboration. It is the purpose of this paper to deal with some mutual interests that must bring movies and television still closer together as time goes on.

It must be immediately obvious that the movie-television partnership is already well under way. Movies play a large part in today's television programming, because film brings the same advantages to television that it has for theater presentation, plus certain other advantages. Film images are of excellent pictorial quality, especially when specifically selected for television reproduction. Film provides a permanent record for use at any time and in any place. Film programs can be handled with a minimum of technical personnel in the television studios, let alone the elimination of actual studio performers or again the mobile pickup unit out in the field.

Just as film permits simultaneous presentation of a program in any number of theaters supplied with prints, so it provides a simple and economical means of syndicating production among any number of scattered television stations.

Also, film overcomes the problems of timing. The film can be produced when and as it is most convenient, yet the film can be shown at any time thereafter. At least half of the news and sporting events happen during the day. Yet the television audience expects to see the televised versions at night. Happily, the film recording spans that awkward gap in timing.

Still another angle: the film recording permits a program to be shown again and again. Until now, with only three television stations sharing time in the New York metropolitan area, the audience has been viewing just the one program available on most evenings. Yet even at this early stage of commercialized television, there have been evenings when two and even three of the original television sta-

tions were on the air simultaneously with outstanding programs actually competing for audience attention. In the future there will be seven stations on the air each evening. The audience will obviously be missing interesting programs, just as much as is missed at a three-ring circus, if we continue the practice of a different show by each station every night. In order that a given show may be enjoyed by the greatest audience, it may be that telecasters will borrow a leaf from the movie industry and repeat their best shows, by means of film recordings. The same show might be run for three evenings in a row, after the manner of neighborhood movie houses. Or the recorded show might be shown again later in the evening or the following afternoon, in order to reach the maximum audience. At any rate, film recordings are to television what the transcribed program is to broadcasting.

In the case of the sponsored program, particularly the so-called "commercial" or advertising plug, film is the ideal means of insuring a uniform identity of product or company. Already many such films have been made and used to good effect in telecast advertising. Such films are carefully produced. The whole world of scenery is available for such shooting. Larger items, such as automobiles, trains, steamers, airplanes, and so on, can best be filmed in their natural settings. Film recordings can then be shown over and over again with that positive uniformity of presentation so vital to good advertising. Film is to television advertising what the stereotype mat is to newspaper advertising—the foolproof reproduction.

Even in studio production, film has its vital place. Time and again a studio production has troublesome gaps or pauses that must be bridged over by some suitable pictorial action, since the television public will not tolerate a blank Teleset screen even for a few seconds. Film "shorts" help fill in such pauses.

Too, television plays have been considerably enhanced by the inclusion of movie scenes, frequently made with the same performers amid the desired outdoor scenes. For instance, if the television play calls for a bit of action, say on Fifth Avenue, or for a train, steamer, bus, or airplane, it is evident that such a scene can best be made outdoors with the same actors, rather than attempt a synthesized version in the studio. Filmed scenes also gain time for shifting from one studio scene to another.

Economically, film production presents certain advantages. Television studio problems can be frequently solved by film shooting.

For one thing, studio space limitations can be overcome by having the production made in a movie studio and recorded on film. Likewise, if the studio schedule is overflowing, the production may be filmed even in the television studio itself, thereby dispensing with the lengthy rehearsals of the live-talent show. If performers are available only at certain times that do not conform with telecasting hours, the film recording again solves the problem. At any rate, the entire production can be filmed and used at will, without tying up limited studio facilities.

Of course the simple performance can be handled at lower cost with studio live talent and direct television pickup. This will always be the logical choice especially when a single television station must bear the entire cost. But for more elaborate productions and where several stations are participating in a syndicated program, then the movie method of production becomes increasingly more attractive. In all cases the cost comparisons should largely settle the choice of direct television pickup of film recording.

Many of the programs handled by Du Mont Television Station *WABD* in New York City are recorded on film as standard production routine. We have a threefold purpose in recording many of our programs:

(*1*) Such films provide a handy record that may be studied by our studio personnel, technicians, and again the performers, directors and writers, to improve their respective talents as time goes on.

(*2*) Such films are supplied to advertisers, as a permanent record of their programs.

(*3*) Such films serve to build up a growing library of recorded programs that can be used again either over our own stations, or syndicated to other stations.

Du Mont technicians have worked for several years on the many problems of recording television images on movie film. We have evolved a satisfactory technique, whereby television images of a repetitive rate of 30 pictures per second on the cathode-ray screen can be recorded on movie film at 24 frames per second or any other rate required. Our own recordings are made on standard 16-mm film, with sound track included, for a completely recorded television program.

The greatest problem in film recording of television programs directly off the cathode-ray tube of the television monitor is the difficulty of synchronizing the 30 frames per second speed of television to

either the 16 frames per second of silent motion pictures or the 24 frames per second of standard sound film.

There are two practical solutions to these problems:

(*1*) To record silent pictures at 15 frames per second using a synchronous motor drive on a standard camera and projecting this film at the standard speed of 16 frames; or

(*2*) Recording at standard sound speed of 24 frames per second using a specially constructed shutter and pull-down in a camera also driven by a synchronous motor. This will allow the film to be projected at sound speed from a standard projector.

15 Frames per Second Silent.—As stated before, television operates at 30 frames per second. If a standard motion picture camera with a shutter of approximately 204 deg is driven by a synchronous motor at 15 frames per second, half of the alternate 30 television frames will be recorded, the other half will be lost during the pull-down time of the camera with the result that 15 frames per second will be recorded. In projecting a film taken by this method at the standard 16 frames per second, no particular speeding up of the subject action is noticeable.

24 Frames per Second.—In recording television 30 frames per second at standard 24-frame sound speed the difficulties are not so easily overcome; however, these problems are almost entirely of a mechanical nature.

Again a synchronous motor is used to drive a standard camera at 24 frames per second, but both the shutter and pull-down mechanism must be altered so that 6 television frames out of every 30 are lost during the pull-down time of the camera, resulting in a 24 frame per second recording of the 30-frame television picture.

As the film travels through the camera at sound speed, sound can be recorded in the usual ways, either on the same film using a single system or by a separate sound camera using a double system.*

The motion picture business is based on sequence of runs, which is based on pricing. So far not enough money has been offered by telecasters for film to warrant any deviation from their normal arrangements. Because of this, it is evident that motion picture producers have been unwilling to supply first-run feature pictures or, for that matter, even news reels or short subjects to telecasters.

Consequently, telecasters have had to depend on entertainment

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* The film shown at the end of this paper was recorded at 15 frames per second, but projected at sound speed with background music and voice dubbed in.

films of more or less ancient vintage—films from which the movie industry has already extracted just about the last dollar of box-office revenue. Speaking for my own organization which has pioneered in telecasting through our New York Station *WABD* (originally Station *W2XWV*), and more recently through our Washington Station *W3XWT*, I cannot point with particular pride to much of our film programming during the past several years. Certainly we would not pick many of the old-time films we have shown as a matter of choice. Along with other pioneer telecasters, we have had to show films of five, ten, and even fifteen years ago. Time and again our audience has witnessed the all-too-obvious turning back of the hands of time as we have flashed on their Teleset screens a less polished Bing Crosby of the early '30s, a precocious Shirley Temple when she was only knee high to a grasshopper, and a youthful Charlie Chaplin at the peak of his career, and so on. The pictorial quality of such ancient times is positively an imposition before the eyes of today's critical audience. Yet such ancient films can prove interesting and worth while at times. Indeed, Station *WABD* has even capitalized the antique touch, and its audience had positively enjoyed such backward glimpses into the "good old days" with the showing of the Charlie Chaplin classics. No one will deny that the libraries of ancient films have been of inestimable help to pioneer telecasters. Such films have served to fill in a third to a half of our evening programs until such time as we have been able to build up our studio live-talent features.

In addition to the ancient films, we have been fortunate in having an ever-increasing supply of documentary films, notably in connection with the war. British and other films have been available to telecasters; also good documentary films produced in this country by governmental bureaus, industrial concerns, universities, and others. Such documentary films can provide fair entertainment at times, although they definitely lean toward enlightenment and even sheer propaganda. But since such films are usually not shown in theaters and may generally go unseen by the general public, television now provides a logical means of making such documentary films available to a general audience.

For years past the producers and sponsors of documentary films have sought an audience for their wares. They knew such an audience existed, but had not the means of reaching it. It would seem to me that television, especially as it reaches out into schools, provides a logical means of bringing worthy documentary films to the

attention of the vast nontheatrical audience. A single print can be shown simultaneously to a huge audience limited only by the number of Telesets that may be installed.

Sooner or later, and it should be soon, telecasters must seek new sources of film. True, there is a rising proportion of studio live-talent material now in the making, but as telecast programs are lengthened to cover afternoons as well as evenings, we may be obliged to use an increasing amount of film entertainment.

The time is coming when television should have suitable film productions of its own. Such films should be geared to television requirements—technically as well as in subject matter. Already some telecasters have covered news events with their own cameramen. Such presentations have been well received by the television audience. Too much cannot be said for the splendid news reporting of such events as the return of General Eisenhower to Washington last summer; the signing of the Japanese surrender aboard the *Missouri* in Tokyo Harbor, telecast a week later to the television audience in the New York area; and the San Francisco meeting of the U.N.O. Much of this news reporting has been handled with 16-mm camera equipment, and it is important to point out that this smaller film televises about on a par with the 35-mm size. Thus the telecaster can work with the convenient and economical 16-mm equipment and film, which is especially significant for the smaller television station covering local news and sports.

Motion picture producers, knowing of the need for better films by the telecasters now on a truly commercial basis, may soon be producing films strictly for television use. That is logically their job. They are now being invited to supply the need. As more and more telecasters take to the air, the economies of special television film productions will be worked out so that this market can prove worth while for film producers.

So far this paper has dealt with the contributions past, present, and future of movies to the up-and-coming art of television. But this movie-television collaboration is definitely a two-way proposition. In time television will contribute much to movie technique, as well as movie economics.

Among the earliest television contributions to the motion picture art is the Du Mont film-recording method of presenting televised events in theaters. Our engineers have long worked on the problems of projecting bright television images of adequate detail on full-sized

theater screens. Today we have high-brilliancy tubes and large aperture lenses for approximating these results. Nevertheless, we have developed another method which offers more satisfactory results by way of recording the television images on film and then projecting the film in the conventional manner.

The Du Mont equipment for this purpose—covered by the broad basic U. S. Patent No. *2,373,114*—includes a high-brilliancy cathode-ray tube carrying the television image. The image is photographed on movie film, along with the sound track. The film is then automatically developed, fixed, rinsed, and dried, ready for conventional projection in a matter of minutes. The film can be cut and spliced, titled and edited, as necessary. The televised news event, taken off the air or coaxial cable, is on the screen almost as soon as it happens, so that it still qualifies as seeing-while-happening reporting. Yet the film makes possible the showing of the event as often as may be desired, which is a prime requisite of the theater or movie house.

The bulk of the revenue for big boxing bouts of the near future will no doubt come from theater television. Likewise, with other sporting events. For the box office is still the logical place to collect for such features, and this television-filmed technique provides the practical means of multiplying the paying audience to untold proportions. This service is not to be confused with usual news reels, since it presents the event in the matter of minutes as against hours for the usual movie version. And a televised event—seen as it happens—must always have fresher and greater box office appeal. Meanwhile, the televised event will also be available to news reels for usual distribution.

The possibilities of television-filming are simply unpredictable. Even at this early date the television studio and its control room may well be the envy of the movie producers. In television we have a plurality of cameras on the studio floor, each transferring its pickup instantly to a respective monitor screen in the control room. The production director has before him the respective pickups of all cameras. By means of the intercommunicating system, with earphones worn by the cameramen, he can instruct any cameraman as to desired shots. Any single pickup can be selected and transferred to the transmitter for placement on the screens of the telesets of the audience. More than that, any combination of scenes can be used by corresponding switching. Also, there are electronic faders, lap dissolves, and other effects largely duplicating movie camera tech-

nique. The control-room operators can obtain simple or intricate montage effects by electronic manipulations of the pickups of two or more cameras, while each component of such a montage is under complete and immediate control.

As an interim step in television-filming, the remote electronic view finder idea may interest movie producers. The usual film cameras are still used in the conventional manner, but attached to such cameras is a miniature television camera which transmits the view finder image to a screen before the director. Thus the director has before him the exact scene for which any camera is set at that given moment. The director can phone the cameraman and give instructions, while viewing the new setup of the camera as such instructions are followed. When the scene is properly set in the electronic view finder, the order to "roll" the camera follows. What such co-ordination could mean to the director of gigantic spectacles, covered by many cameras in scattered locations, is left to your imagination.

As time goes on the pictorial quality of televised images will steadily improve until it is on a par with motion picture film. Television-film recording will then be fully feasible, with television cameras transferring their images to a central control room where the director and his technicians will select the choicest scenes and actions for recording.

Another fascinating television-filming possibility is found in the growing sensitivity of the television cameras. The new image-orthicon tube, with a sensitivity 100 times greater than that of previous television tubes, now picks up scenes in moonlight, by candle-light, and in any kind of weather. Already we have reached a point in television camera technique whereby poorly lighted scenes that cannot be filmed directly on film emulsions can now be recorded through the intermediary of television. An entirely new world of movie possibilities is opened up by this supersensitive television pickup.

Television is certain to be a powerful influence in future educational methods. Telesets placed in various classrooms can bring an educator or lecturer or educational features before vast numbers of students at one time. This facility may well have an important bearing on the economics of visual education films, since a single print can now be shown simultaneously to many different classes and in many different schools at one time, through telecasting over cable and over the air.

Television likewise finds its place in the merchandising field. In addition to its use in theater, home, and school, television is entering the department store for the purpose of reaching more people in more departments with the offerings of other departments. Telesets are located at strategic points throughout the large department store. A center studio is set up, with the necessary cameras and associated equipment. Before the cameras may be placed certain goods to be displayed, or models to fashion the latest garments, or a demonstrator with something to demonstrate. Instantly the image and the voice are made available at strategic points throughout the store, thereby overcoming to a large degree the penalty that has been paid heretofore for magnitude.

In place of the live pickup, suitable merchandising films may be used. Or the given live-talent pickups may be recorded on films for repetition. Again television and film work hand in hand.

There are many heretofore inaccessible places to be filmed. Conventional equipment is cumbersome, and lighting conditions may be hopeless with usual film emulsions. But here again, television can step in. Television cameras, devoid of moving parts and motors, can be reduced to extreme compactness and light weight, if these are the prime considerations. Such cameras can be carried to places heretofore considered inaccessible, and the pickups flashed over coaxial cable or ultra-short-wave link to a central recording point where the images are copied on film. The production director at the central point can follow the camera work and ask for precisely what he wants.

Movies and television are natural partners. One supplements the other. Movies are the permanent record. Television is the more advanced way of getting the picture. Television owes much to movies up to this time. But from here on movies will be receiving increasing benefits from the rapidly refining television technique.

NONINTERMITTENT MOTION PICTURE PROJECTOR WITH VARIABLE MAGNIFICATION*

F. G. BACK**

Summary.—*In the course of the Navy aviation training program, a projector had to be designed to project the image of a target vessel on a curved cyclorama screen, and to make this projected image perform all the real and apparent motions of an actual battleship, as seen from the cockpit of a maneuvering aircraft.*

The projected image had to wander all around the horizon. It had to become larger and smaller under due consideration of the angle of depression corresponding to that particular range. Also, the projected target had to be able to make all kinds of turns and maneuvers to simulate actual combat conditions. To achieve all this a special nonintermittent 16-mm film projector for variable speed and variable magnification was built, and is described in the following paper.

The problems confronting the motion picture projector designer in the past have been many and varied, but never has it been his task to cast upon the screen an image which executes various movements at the operator's command through remote electronic control.

To produce a satisfactory Naval Aviation Training Projector the image of a military object has to move around the spectator; it has to vary in distance from the spectator, and it must make movements around its own vertical axis. A combination of these movements must give the same impression as viewed by an aerial gunner under actual battle conditions.

All these movements must be performed at different speeds in all possible directions strictly related to electrically controlled devices at the operator's command, and in relation to target movements.

After intensive and thorough research it was found that the best performance could be obtained only with a specially developed nonintermittent motion picture projector fixed in the center of a cycloramic screen.

To solve the problem, the required independent motions were re-

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* Presented Oct. 15, 1945, at the Technical Conference in New York.

** Research and Development Laboratory, 381 Fourth Ave., New York.

garded as basic movements, the combination of which would result in the required performance.

The basic movements are as follows:

(*1*) The movement of the image around the observer,

(*2*) The movement of the image toward and away from the observer,

(*3*) Altering the angle of depression under which the image on the screen is seen,

(*4*) The movement of the image around its own axis.

The first component movement is comparatively simple; the image has to move around a horizon in the cyclorama. It is effected by rotating the whole projector around its own vertical axis, Fig. 1*A*.

The second component movement (the movement toward and away from the observer) is achieved by a special varifocal projection optic. This special optic allows the change of magnification without changing the location of the object or the image; namely, the film and the screen, and without impairing the optical quality of the image.

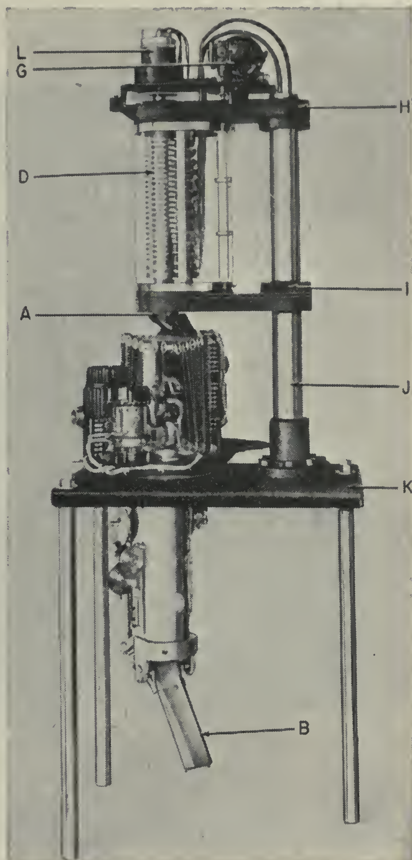

FIG. 1. Projector on demonstration stand.

The angle of depression, under which the image on the screen of the cyclorama is seen, is changed by the movement of a mirror *B* which deflects the projection beam (Figs. 1 and 2).

The fourth component movement (the movement of the image around its own axis) is obtained through a special nonintermittent film transport mechanism with a 16-face prism as optical compensator, which allows an endless film loop to project, with variable speed,

backward and forward, without slippage or play. The endless film loop, which is 16 ft long, shows a complete revolution of the target around it own vertical axis.

By the use of remote control it is possible to operate the projector by combining either *all* basic movements, or by using only *requested* movements; *e. g.*, a combination of the movement toward the ob-

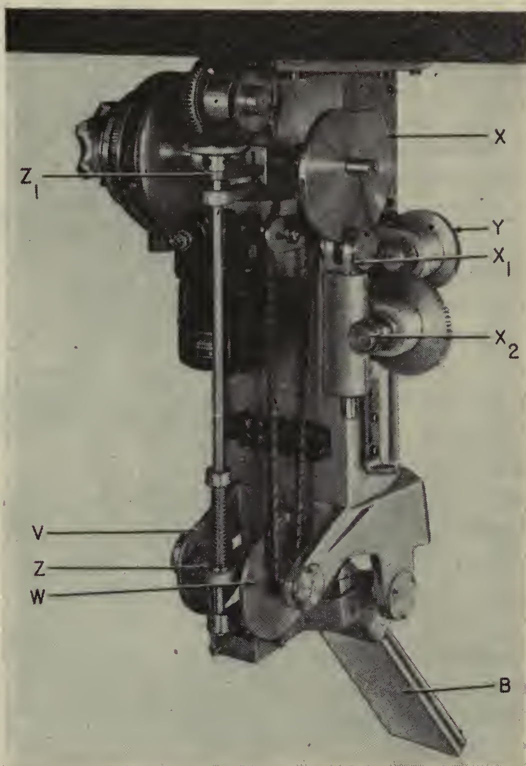

FIG. 2. Optical system.

server with the movement of the image around its own axis would result in the following illusion: The observer sees the image under a certain angle of depression coming toward him, becoming larger and larger by means of the varifocal projection optic. At the same time, the operator turns the image by starting the nonintermittent film transport mechanism.

If the operator lets the image make only a partial turn and reverses this movement by letting the projector run backward, and repeats this action, the observer then gets the impression that the image meanders. The above-described movement combination can be performed at any required speed and as often as desired according to the revolution of the projector mechanism.

It is possible, if required, to repeat this performance under another angle of depression, thus giving the observer the impression that he is viewing the whole performance from another altitude. This image

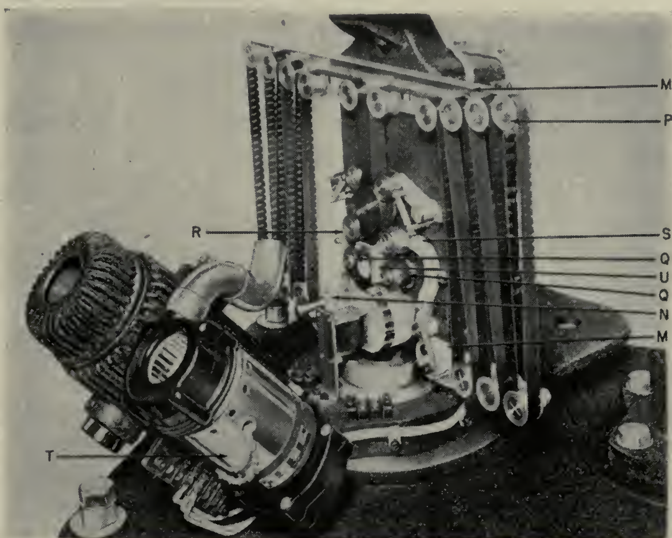

FIG. 3. Projector mechanism.

performance can be varied according to the given requirements and can be combined with the movement around its own axis. The image then travels around the cycloramic screen.

The speed of all the above-described movements, either separately or combined, is controlled by the use of electronic devices and registered on a central control point at the operator's desk. On this control point is also registered the reaction of the observer relative to the movements of the target image. This makes it possible for the operator to perform all target movements at the speed required by the simulated conditions set up in the various phases of the training program.

Consequently, the design of this instrument, built with the utmost precision, had to follow in the outline the mechanical requirements which would produce a perfect illusion.

(*1*) The vertical drive (Fig. 1*G*), which produces the movement around the observer, including the slip-ring arrangement (Fig. 1*D*),
(*2*) The nonintermittent film transport mechanism (Fig. 3),
(*3*) The lens tube arrangement (Fig. 2), which produces the movement of the image toward and away from the observer, and altering the angle of depression under which the image on the screen is seen by the observer.

The vertical drive, together with the nonintermittent film transport mechanism is the upper unit of the projector. The lens tube with the mirror (Fig. 2) is the lower unit.

The vertical drive (Fig. 1) comprises the slip-ring arrangement (*D*); drive motor (*G*), the upper and lower arm, (*H*, *I*), which supports the whole unit with the aid of the column (*J*) on the base plate (*K*).

The motor (*L*) is a Selsyn motor, part of the electronic equipment which signals the required actions. The slip-ring arrangement makes it possible to locate the various necessary connections for the electric remote control system in central position. It is fixed to the projector body and forms the axis around which the projector turns.

The projector body (Fig. 3) carries on its base plate the film drive motor, together with a Selsyn motor.

Attached to two fixed arms (*M*) and one pivoted idler arm (*N*) are 16 film idler rollers (*P*) which guide the endless film loop.

Two guide rollers lead the film in the sprocket which transports the film.

Two special gate rollers (*Q*) are mounted above the 16-face prism. One compensating arm (*R*) and one framing arm (*S*) enable the operator to obtain the correct frame.

The light source is a 1000-w projection lamp. A blower motor (*T*) with two fans serves for cooling purposes. The lamp house can be tilted backward, as shown, to facilitate the changing of the endless film loop. The light beam is transmitted through a special aplanatic condenser, which gives a maximum of illumination without applying undue heat to the film. A 90-deg deflecting prism (*U*) an integral part of the condensing system, changes the direction of the light beam from horizontal to vertical.

The lens tube arrangement contains the optical system, the mirror, and in addition, all the necessary electrical and mechanical equipment to co-ordinate the various movements which are essential to achieve

the desired requirements, namely, changing the size of image, altering the angle of depression, and retaining the brightness of the projected image.

In Fig. 2, the cams (V, W, X) are turned by a small electric motor which gets its signals through remote control. Microswitches prevent over-travel in the entire system.

The lens tube is flanged to the projector body and rotates with it.

The optic of the lens tube consists of two objectives, one short-focus and one long-focus. The short-focus lens produces a real image of the film in a field lens, and this image in turn is cast upon the screen by the long-focus objective with the aid of the deflecting mirror (B). The change of magnification is obtained by moving the short-focal lens relatively to the film and by compensating the resulting change in focus with an appropriate movement of the long-focus lens.

It was found after plotting the necessary movements of the two lenses against the range, to which the required image size is co-ordinated, that one lens movement is linear, while the other movement follows an irregular curve of the fourth order. The linear movement was achieved by using a steel tape rolled on a disk (Y). The irregular movement was effected by the use of the cams (X), roller, rack, (X_2) combined with the disk and steel tape (Y). The cams (V, W) are connected with a mirror bracket (B). They are used selectively, depending on the required altitude. The changing from one cam to the other is accomplished by using the clutch (Z), and the lever movement with the aid of the shift lever (Z_1).

Fig. 1 shows the assembled projector as it was installed in the various Navy establishments (with the exception of the three chromium-plated legs attached to the base plate, which have been used for demonstration purposes only. They are replaced by special fixing bolts.)

A number of these projectors have been in use for some time in various Navy Training Centers.

A FILM-SPLICING AND REPAIR MACHINE*

ARMOUR WALLINGSFORD**

Summary.—*Editing film with its constant splicing and movements through moviola, synchronization, and projection machines subjects the prints to severe wear and damage. Splices and repairs must be made speedily and accurately. Time also is an important factor in meeting the release date.*

This paper describes a new type of splicing machine which does not use cement, heat, or require scraping of film.

This machine is a compact portable metal device capable of making straight or diagonal splices, restoring lost and torn perforations, and repairing either picture or sound tract without replacing sections. This is accomplished by the application of a good quality of pressure-sensitive tape which is applied to the film and perforated in exact registration with the film perforations. By using a specially prepared tape, any splice may be "blooped" as it is made without extra operations.

The splicer is composed of a cutting anvil which removes one complete frame or any desired section of film, and a splicing anvil which completes the straight or diagonal splice, makes the perforations, and trims the edges. The perforating is controlled by four retractable registration pins which may be operated in unison, or in any desired combination. An upper arm containing eight punches, a pressure plate and trimming shears, when lowered onto the die anvil completes the film splice on one side. When this operation is repeated on the reverse the splice is ready for use.

The tape is contained in a readily accessible built-in housing which facilitates easy replacement of the roll.

The film splicer reduces, by approximately one-half, the manual movements required by the present method. It can be placed on the editor's table, and splices may be made without removing the reels, thus eliminating the use of paper clips.

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* Presented Oct. 15, 1945, at the Technical Conference in New York.

** Editorial Sound Department, Republic Studios, North Hollywood, Calif.

At the present time the three models of this machine for 8-, 16-, and 35-mm film are in the process of development. The description herein is made from the author's model which has been in constant use for the past six months in the Editorial and Sound Department of Republic Studios, North Hollywood, California. The machine was in actual use splicing picture and sound track area without effecting sound track for dubbing purposes. This was accomplished without a single failure.

The cutter is a stationary split anvil. It has four registration pins, two on each side. The machine improvements will include four other retractable pins for the preparation of diagonal splices. Two holding bars are hinged to fit over the register pins and anvil to hold the

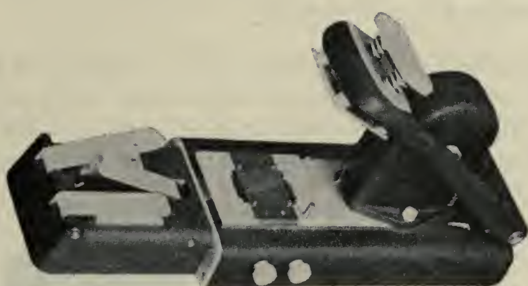


Fig. 1. Cello-vision splicing machine showing film cutter, stationary anvil, tape container, and overhead male punch.

film in cutting. A cutting bar is also hinged on the opposite side of the anvil and cuts out one frame of the film. The cut is designed to produce sufficient overlap for the next operation of splicing.

The splicing anvil is also stationary and consists of a male and female punch die. The female die has eight perforations which are the same dimensions as film perforations. It is also provided with a set of four registration pins which may be retracted independently of each other by the use of four separate cams, which are controlled by two knobs.

The male punch, is mounted on the frame, is a hinged *U*-arm which is held in the open position by a spring. The punch has eight punches to fit the female die. It is also provided with a pressure plate to maintain the film in correct alignment during the splicing

operation. The punch also contains two trimming or shear cutters which coincide with the exact width of the film.

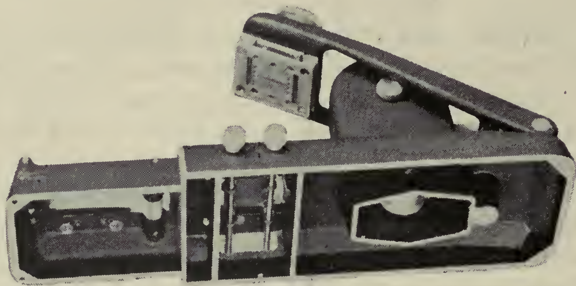


FIG. 2. Subview of cam-operated knobs controlling movement of registration pins in order to restore perforations and make repairs.

The film is placed on the cutting anvil and the desired cut is made. The adhesive, which is a pressure-sensitive tape, is now obtained from a container which is a part of the machine itself. Sufficient tape is pulled out and the end is fixed on the near side of the splicing anvil

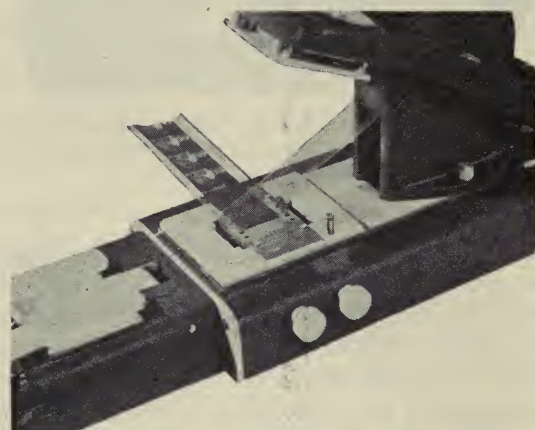


FIG. 3. Tape from container in position and cut end of film ready for splicing.

in readiness to make the splice. The ends of the film are placed on the registration pins of the anvil in overlap relation under the adhesive tape. The adhesive tape is now brought down on the film and the anvil by mere finger pressure.

The overhead punch is brought down and perforates and trims the adhesive tape from the edges in a single operation. The splice is now cemented on one side. The film is turned over and the operation is repeated on the other side of the film to complete the splice.

The machine is capable of making straight and diagonal splices, and by the use of a special prepared tape, it will bloop automatically every splice that is desired. Repairs may be made on any type of break or tear without replacing the damaged sections, in sound track or picture. Repairs have been made on push-pull modulation where the tear occurred in the perforations and sound track area without noise for dubbing purposes. This is accomplished with the application of the tape to the damaged section and in successive operations of the punch.

AMERICAN STANDARDS ON MOTION PICTURES

FOREWORD

The six newly revised American Standards on Motion Pictures published here were recently approved by the American Standards Association and represent another forward step in the present program of motion picture standardization. All such existing standards within the scope of Sectional Committee Z22 of the ASA have been reviewed within the past year, and the first 20 revisions appeared in their new distinctive format in the April 1946 JOURNAL. The six following comprise the second group in this series, published first in the JOURNAL and then made available to the industry, on $8^1/_2 \times 11$-in. sheets, punched to fit the new SMPE Standards Binder.

Revision of the first three of these Standards, *Z22.28*, *Z22.29*, and *Z22.31*, consists of title changes required by current American Standards Association editorial policy. Revision of the other three Standards, *Z22.37*, *Z22.38*, and *Z22.39*, which were originally published in the August 1944 JOURNAL, had been at first thought unnecessary, but title inconsistencies between two printed versions of the three standards, together with a desire to have all *Z22* Standards fit the new binder, seemed to justify having them set in the new format.

Copies of these six Standards, and the twenty published in the April 1946 JOURNAL, may be secured from the General Office of the Society.

AMERICAN STANDARDS

Z22.28-1946	Projection Rooms and Lenses for Motion Picture Theaters
Z22.29-1946	Theater Projection Screens
Z22.31-1946	Motion Picture Safety Film
Z22.37-1944	Raw Stock Cores for 35-Mm Motion Picture Film
Z22.38-1944	Raw Stock Cores for 16-Mm Motion Picture Film
Z22.39-1944	Screen Brightness for 35-Mm Motion Pictures

American Standard Dimensions for

Projection Rooms and Lenses for Motion Picture Theaters

ASA
Reg. U. S. Pat. Off.
Z22.28-1946
First Edition
Z22.28-1941

1. Projection Lens Height

1.1 The standard height from the floor to the center of the projection lens of a motion picture projector should be 48 inches.

2. Projection Angle

2.1 The projection angle should not exceed 12 degrees.

3. Observation Port

3.1 The observation port should be 12 inches wide and 14 inches high, and the distance from the floor to the bottom of the openings shall be 48 inches. The bottom of the opening should be splayed 15 degrees downward. If the thickness of the projection room wall should exceed 12 inches, each side should be splayed 15 degrees.

4. Projection Lens Mounting

4.1 The projection lens should be so mounted that the light from all parts of the aperture shall traverse an uninterrupted part of the entire surface of the lens.

5. Projection Lens Focal Length

5.1 The focal length of motion picture projection lenses should increase in ¼-inch steps up to 8 inches, and in ½-inch steps from 8 to 9 inches.

6. Projection Objectives, Focal Markings

6.1 Projection objectives should have the equivalent focal length marked thereon in inches, quarters, and halves of an inch, or in decimals, with a plus (+) or minus (−) tolerance not to exceed 1 percent of the designated focal length also marked by proper sign following the figure.

NOTE: Complete plans for projection rooms are contained in the *Journal of the Society of Motion Picture Engineers*, p 484, November, 1938.

American Standard Dimensions for
Theater Projection Screens

ASA
Reg. U. S. Pat. Off.
Z22.29-1946
First Edition
Z22.29-1941

1. Screen Size

1.1 Sizes of screens shall be in accordance with the table below.

2. Grommet Spacing

2.1 The spacing of grommets shall be 6 inches. In rare instances, however, 12 inches will be permitted. The ratio of width to height of screens shall be 4 to 3.

3. Screen Placement

3.1 The width of the screen should be equal to approximately 1/6 the distance from the screen to the rear seats of the auditorium. The distance between the front row of seats and the screen should be not less than 0.87 foot for each foot of screen width.

Screen Sizes

Size No. of Screen	Picture Width (Feet)	Picture Height, Feet	Picture Height, Inches	Size No. of Screen	Picture Width (Feet)	Picture Height, Feet	Picture Height, Inches
8	8	6	0	25	25	18	9
9	9	6	9	26	26	19	6
10	10	7	6	27	27	20	3
11	11	8	3	28	28	21	0
12	12	9	0	29	29	21	9
13	13	9	9	30	30	22	6
14	14	10	6	31	31	23	3
15	15	11	3	32	32	24	0
16	16	12	0	33	33	24	9
17	17	12	9	34	34	25	6
18	18	13	6	35	35	26	3
19	19	14	3	36	36	27	0
20	20	15	0	37	37	27	9
21	21	15	9	38	38	28	6
22	22	16	6	39	39	29	3
23	23	17	3	40	40	30	0
24	24	18	0				

American Standard Definition for

Motion Picture Safety Film

ASA
Reg. U. S. Pat. Off.
Z22.31-1946
First Edition
Z22.31-1941

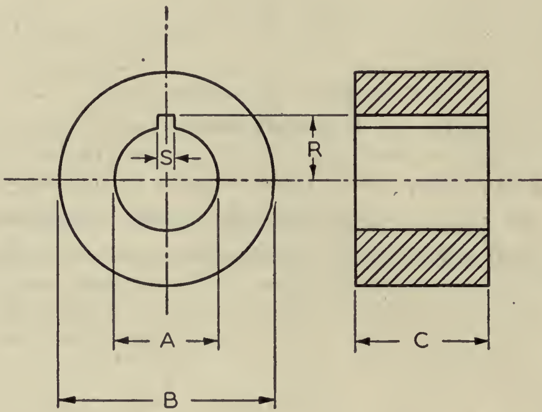
1. Safety Film

1.1 The term "Safety Film" as applied to motion picture materials shall comply with American Standard Definition of Safety Photographic Film Z38.3.1-1943. All 32-mm, 16-mm, and 8-mm film must be of the safety type.

American Standard

Raw Stock Cores For 35-Millimeter Motion Picture Film

ASA Reg. U. S. Pat. Off.
Z22.37-1944



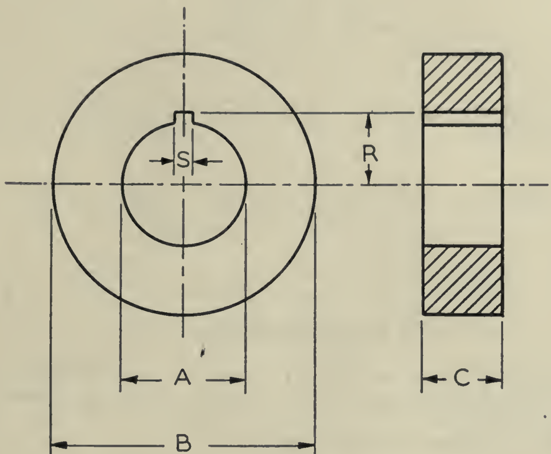
	Millimeters	Inches
A	25.90 ± 0.20	1.020 ± 0.008
B	50.00 ± 0.25	1.968 ± 0.010
C	34.50 ± 0.50	1.358 ± 0.020
Recommended Practice		
R	16.70 ± 0.30	0.657 ± 0.012
S	4.00 ± 0.20	0.157 ± 0,008

Bore A to fit freely to hub 25.40 ± 0.1 mm or
1.000 ± 0.004-inch diameter.

NOTE: Reprinted August 1946, without change.

American Standard
Raw Stock Cores For 16-Millimeter Motion Picture Film

ASA
Reg. U. S. Pat. Off.
Z22.38-1944



	Millimeters	Inches
A	25.90 ± 0.20	1.020 ± 0.008
B	50.00 ± 0.25	1.968 ± 0.010
C	15.50 ± 0.50	0.610 ± 0.020
Recommended Practice		
R	16.70 ± 0.30	0.657 ± 0.012
S	4.00 ± 0.20	0.157 ± 0.008

Bore A to fit freely to hub 25.40 ± 0.1 mm or 1.000 ± 0.004-inch diameter.

NOTE: Reprinted August 1946, without change.

American Standard

Screen Brightness For 35-Millimeter Motion Pictures

ASA Reg. U. S. Pat. Off.
Z22.39-1944

1. Screen Brightness

1.1 The brightness at the center of a screen for viewing 35-mm motion pictures shall be 10 $\pm^{4}_{1}$ foot-lamberts when the projector is running with no film in the gate.

NOTE: Reprinted August 1946, without change.

60th SEMIANNUAL CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL
Hollywood, California

OCTOBER 21–25, 1946

Officers in Charge

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General Office, New York

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Ladies Reception Committee Hostess	MRS. H. W. MOYSE
Projection Program—35-mm	W. V. WOLFE, *Chairman, assisted by* Members Los Angeles Locals 150 and 165
16-mm	H. W. REMERSCHEID

HOTEL RESERVATIONS AND RATES

The Hollywood-Roosevelt Hotel, Hollywood, Calif., will be the Convention Headquarters, and the hotel management extends the following per diem room rates, European plan, to SMPE members and guests:

Room with bath, one person	\$4.40–5.50
Room with bath, two persons, double bed	\$5.50–6.60
Room with bath, two persons, twin beds	\$6.60–7.70

Desired accommodations should be booked *direct* with Stewart H. Hathaway, Manager of the hotel, who advises that no parlor suites will be available unless confirmed by him. All reservations are subject to cancellation prior to October 14, and *no reservations will be held after 6:00 p.m.* on the anticipated date of arrival unless the hotel management has been advised otherwise.

Your Convention Vice-President has arranged with the management of the Hotel Sir Francis Drake, San Francisco, Calif., to provide accommodations for members who will visit this city while on the West Coast. Accordingly, reservations should be made *direct* with George T. Thompson, Managing Director, at least two weeks in advance of expected arrival in San Francisco. When making reservations, advise Mr. Thompson that you are a member of the SMPE.

REGISTRATION

The Convention Registration Headquarters will be located in Room 201 on the mezzanine floor of the hotel, where Luncheon and Dinner-Dance tickets can be procured prior to the scheduled dates of these functions. Members and guests are expected to register. The fee is used to help defray Convention expenses.

BUSINESS AND TECHNICAL SESSIONS

Day sessions will be held in the hotel, and evening sessions at locations away from the hotel, as given below.

GET-TOGETHER LUNCHEON AND DINNER-DANCE

The Society will again hold its regular pre-war social functions and accordingly a Get-Together Luncheon is scheduled in the California Room of the hotel on Monday, October 21, at 12:30 P.M. The guest speaker will be Byron Price. Members in Hollywood and vicinity will be solicited by a letter from S. P. Solow, Secretary of the Pacific Coast Section, to send remittances to him for the Convention registration fee and luncheon tickets. Ladies are welcome to attend the luncheon.

The 60th Semiannual Dinner-Dance will be held in the California Room of the hotel on Wednesday evening, October 23, at 8:30 P.M. Dancing and entertainment. (Dress optional.) A social hour for holders of Dinner-Dance tickets will precede the Dinner-Dance between 7:15 P.M. and 8:15 P.M. in the Hotel Terrace Room (Refreshments).

LADIES' PROGRAM

A reception parlor for the ladies' daily get-together and open house with Mrs. H. W. Moyse as hostess will be announced on the hotel bulletin board and in the final printed program.

Ladies are welcome to attend technical sessions of interest, also the Luncheon on October 21, and the Dinner-Dance on October 23. The Convention badge and identification card will be available to the ladies by applying at Registration Headquarters.

The ladies' entertainment program will be announced later.

MOTION PICTURES AND RECREATION

The Convention recreational program will be announced later when arrangements have been completed by the local committee. Identification cards issued only to registered members and guests will be honored at the following *deluxe* motion picture theaters on Hollywood Boulevard:

Egyptian Theatre
Grauman's Chinese Theatre
Hollywood Pantages Theatre
Hollywood Paramount Theatre
Warner's Hollywood Theatre

Technical Sessions Scheduled

A Tentative Program and abstracts of papers were recently mailed to the general membership of the Society in the United States. The complete program as followed during the Convention will be published in the November JOURNAL. However, for those who failed to receive the Tentative Program, the technical sessions scheduled, location, and time are given here to facilitate making plans.

Monday, October 21, 1946

Open Morning.

10:00 a.m. *Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Luncheon and Dinner-Dance tickets.

12:30 p.m. *California Room:* **SMPE Get-Together Luncheon.**

2:00 p.m. *Aviation Room, Hotel Mezzanine Floor:* **Opening business and Technical Session**

8:00 p.m. **Evening Session:** Republic Studios Scoring Stage, Hollywood.

Tuesday, October 22, 1946

Open Morning.

10:00 a.m. *Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Dinner-Dance tickets.

2:00 p.m. *California Room:* **Afternoon Session.**

8:00 p.m. **Evening Session:** Paramount Studios, Hollywood.

Wednesday, October 23, 1946

9:30 a.m. *Room 201, Hotel Mezzanine Floor:* **Registration.** Advance sale of Dinner-Dance tickets.
10:00 a.m. *California Room:* **Morning Session.**
Open Afternoon.
7:15 p.m. *Hotel Terrace Room:* A social hour for holders of Dinner-Dance tickets preceding the Dinner-Dance (Refreshments).
8:30 p.m. *California Room:* **60th Semiannual Convention Dinner-Dance.** Dancing and entertainment.

Thursday, October 24, 1946

Open Morning.
1:00 p.m. *Room 201, Hotel Mezzanine Floor:* **Registration.**
2:00 p.m. *California Room:* **Afternoon Session.**
8:00 p.m. **Evening Session:** Walt Disney Theater, Disney Studios, Burbank.

Friday, October 25, 1946

Open Morning.
2:00 p.m. *California Room:* **Afternoon Session.**
8:00 p.m. **Evening Session:** Marquis Theater, Hollywood.

Note: All sessions during the 5-day Convention will open with an interesting motion picture short.

Important

Because of the existing food problem, your Luncheon and Dinner-Dance Committee must know in advance the number of persons attending these functions in order to provide adequate accommodations.

Your cooperation in this regard is earnestly solicited. Luncheon and Dinner-Dance tickets can be procured from W. C. Kunzmann, Convention Vice-President, during the week of October 13 at the Hollywood-Roosevelt Hotel.

All checks or money orders for Convention registration fee, Luncheon and Dinner-Dance tickets should be *made payable* to W. C. Kunzmann, Convention Vice-President, and *not* to the Society.

W. C. Kunzmann
Convention Vice-President

SOCIETY ANNOUNCEMENTS

AMENDMENT TO BY-LAWS

During the past year the Board of Governors has received several requests to establish Student Chapters of the Society in educational institutions of recognized standing. Since no provision exists in the Constitution and By-Laws which would permit establishment of Student Chapters, the Board of Governors, at a meeting held July 10, 1946, considered and submits the following new proposed

By-Law for consideration by the membership. The proposal is published herewith in accordance with By-Law XII, Section 1, and will be voted on by qualified members at the 60th Semiannual Convention, Hollywood-Roosevelt Hotel, Hollywood, Calif., October 21–25.

Proposed By-Law XIII

Student Chapters

"*Sec. 1.*—Student Chapters of the Society may be authorized in any college, university, or technical institute of collegiate standing.

"Upon written petition, signed by 12 or more Society members, or applicants for Society membership, and the Faculty Adviser, for the authorization of a Student Chapter, the Board of Governors may grant such authorization.

Chapter Membership

"*Sec. 2.*—All members of the Society of Motion Picture Engineers in good standing who are attending the designated educational institution shall be eligible for membership in the Student Chapter, and when so enrolled they shall be entitled to all privileges that such Student Chapter may, under the General Society's Constitution and By-Laws, provide.

"*Sec. 3.*—Should the membership of the Student Chapter fall below ten, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

Chapter Officers

"*Sec. 4.*—The officers of each Student Chapter shall be a Chairman and a Secretary-Treasurer. Each Chapter officer shall hold office for one year, or until his successor is chosen. Officers shall be chosen in May to take office at the beginning of the following school year. The procedure for holding elections shall be prescribed in Administrative Practices.

Faculty Adviser

"*Sec. 5.*—A member of the faculty of the same educational institution shall be designated by the Board of Governors as Faculty Adviser. It shall be his duty to advise the officers on the conduct of the Chapter and to approve all reports to the Secretary and the Treasurer of the Society.

Chapter Expenses

"*Sec. 6.*—The Treasurer of the General Society may deposit with each Chapter Secretary-Treasurer a sum of money, the amount to be fixed by the Board of Governors. The Secretary-Treasurer shall send to the Treasurer of the General Society at the end of each school year, an itemized account of all expenditures incurred during that period.

Chapter Meetings

"*Sec. 7.*—The Chapter shall hold at least four meetings per year. The Secretary-Treasurer shall forward to the Secretary of the General Society at the end of each school year a report of the meetings for that year, giving the subject, speaker, and approximate attendance for each meeting."

EMPLOYMENT SERVICE

POSITIONS OPEN

The Communicable Disease Center of the U. S. Public Health Service is engaged in the production and distribution of motion pictures, lantern slides, film strips, and other audio-visual aids to be used as media of information and instruction for colleges, universities, public health agencies, and other groups. The above agency is currently recruiting for a number of positions open to experienced technicians at salaries ranging from $3397.20 to $8179.50 per annum. Because of lack of space, details of only six of the 16 positions available are given in this issue of the JOURNAL; others will be listed next month. Applicants should address inquiries to Personnel Officer, U. S. Public Health Service, 605 Volunteer Building, Atlanta 3, Georgia.

(1) PROJECT SUPERVISOR, $4902 per annum, requiring a thorough knowledge of production of technical training films. Applicants must supervise and advise employees in production analysis, choice of script, plotting sequence, and other related duties in film production.

(2) CHIEF, DEVELOPMENT BRANCH, $5905.20 per annum, requiring responsibility for the development of training films and collateral aids in field of communicable disease. Must incorporate factual data, outline background and objectives to subordinate employees, review completed plans, and make final evaluation of production for policy, context, and effectiveness.

(3) CHIEF, UTILIZATION SECTION, $5905.20 per annum. Requires a thorough knowledge of the utilization and evaluation of audio-visual aids as applied to the dissemination of information. Must be able to recommend changes in substance of films, maintain liaison with various agencies, both domestic and foreign, determine appropriate film for given group, maintain continuous analysis of the production program, and formulate distribution program.

(4) CHIEF, PRODUCTION BRANCH, $4902 per annum, requiring a thorough knowledge of the production of training films, including motion picture production management, laboratory techniques, sound recording, film editing, animation, slide series, and other closely related operations. Must be able to give executive direction to Chief of Motion Picture Section, Chief of Film Strip Section, Chief of Graphics, and other necessary personnel.

(5) CHIEF, FILM STRIP SECTION, $4149.60 per annum. Applicants must have a thorough knowledge of photography, both still and motion picture, color photography, photomicrography, sound recording and music effect, recorded narration and dialogue, and other related fields. Work is reviewed for propriety, effectiveness, and conformance with project objective and general training film policy.

(6) CHIEF, PRODUCTION DIVISION, $7102.20 per annum. Responsible for the execution of the entire production and distribution program in the field of audio-visual training as applied to communicable disease control. Will be responsible for the improvement of the present program, liaison with organizations or institutions concerned with communicable disease control, evaluation and utilization analysis of training methods, direct a staff of 50 to 60 people.

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Motion picture studio in Bombay, India, has positions open for professional motion picture camerman with studio and location experience; sound recording engineer experienced in installation, maintenance and

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We are grieved to announce the deaths of John E. McAuley, Fellow of the Society, on August 22, 1946, in Chicago, Ill., and F. C. Coates, Active member of the Society, on September 7, 1946, in Los Angeles, Calif.

SOCIETY of MOTION PICTURE ENGINEERS

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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 **OCTOBER 1946** **No. 4**

CONTENTS

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A UNIFIED APPROACH TO THE PERFORMANCE OF PHOTOGRAPHIC FILM, TELEVISION PICKUP TUBES, AND THE HUMAN EYE*

ALBERT ROSE**

Summary.—*The picture pickup devices—film, television pickup tube, and eye—are subject ultimately to the same limitations in performance imposed by the discrete nature of light flux. The literature built up around each of these devices does not reflect a similar unity of terminology. The present paper is exploratory and attempts a unified treatment of the three devices in terms of an ideal device. The performance of the ideal device is governed by the relation*

$$\textit{scene brightness} = \textit{constant}\ \frac{(\textit{signal-to-noise ratio})^2}{\textit{picture element area} \times \textit{quantum efficiency}}$$

The three devices are shown to approximate this type of performance sufficiently well to use it as a guide in treating their common problems. Simple criteria are derived for characterizing the performance of any one device as well as for comparing the performance of different devices. For example, quantum efficiency is used to measure sensitivity; the signal-to-noise ratio, associated with a standard element area, is used to measure both resolution and half-tone discrimination. The half-tone discrimination of the eye governs the visibility of "noise" in the reproduced picture and, in particular, requires that pictures be photographed or picked up at increased scene brightness when the brightness of the reproduction is increased. The observation and interpretation of visual "noise" are discussed.

Introduction.—There are three picture pickup devices that have separately been the subject of considerable investigation. These are the human eye, motion picture film, and television pickup tubes. For each of these, a large technical literature has been built up relatively independently of the others. The language, the units, the concepts, and the conclusions of the separate arts are not in a form that allows them to be readily compared. This situation is understand-

* Presented May 10, 1946, at the Technical Conference in New York.

** RCA Laboratories, Princeton, N. J.

able in the early stages of the arts because the primary emphasis is then to get something—anything—that will transmit a usable picture. As the art progresses, however, interest shifts naturally to an examination of the theoretical limits of expected improvements. Such an examination is especially significant because all three devices are subject ultimately to the same simple statistical limitations arising from the discrete nature of light flux. The time is opportune for the three devices to profit from a consideration of their problems in common terms.

Some illustrations will make the present situation clear. In films, graininess is a familiar concept. Its origin, control, and visual effects have been treated extensively and for a long time. In pickup tubes, signal-to-noise ratio is an ever-present consideration for getting pictures of good quality. For human vision, interest has frequently been centered on the minimum discernible contrast. There is good reason now to say that graininess, signal-to-noise ratio, and minimum discernible contrast are only three different names for the same property of a picture pickup device. Again: the limiting resolution of film is a standard and advertised characteristic; the frequency response curve of a television pickup tube is an important specification of the tube's performance; the minimum resolvable angle of the eye is a well-known figure and one which, perhaps, has received more than its just share of attention. It is obvious that in all three instances, an attempt has been made to count the number of separate picture elements.

A third illustration concerns sensitivity. There is little need to remind one of the variety and confusion of sensitivity scales that have been proposed for film. On the other hand, the sensitivity of a television pickup tube can, with reasonable adequacy, be defined by its microampere signal output per lumen input. The sensitivity of the eye has variously, and often with deliberate dramatic emphasis, been described in terms of the farthest distance at which one can still see a lighted candle; the order of magnitude of the faintest visible star; the number of lumens falling on the retina necessary for a visual sensation; and so on. Only recently have there been more fundamental attempts to measure the sensitivity of the eye in terms of its quantum efficiency.

These illustrations serve to show, first, that the basic properties of a picture pickup device—resolution, sensitivity, and contrast discrimination—are indeed of common concern to the eye, film, and pickup

tube; and, second, that the specification of these properties has not enjoyed an appropriately common treatment.

The purpose of the present discussion is to explore the extent to which such a common or unified treatment is both possible and profitable.

The order of the discussion will be:

(*1*) The development of the properties of an ideal picture pickup device;

(*2*) The examination of eye, film, and pickup tube for the purpose of finding out how well they approximate ideal performance;

(*3*) A re-examination of a number of current problems in the light of (*1*) and (*2*).

It will become clear that the performance of an ideal device is completely specified by a single number, the quantum efficiency of its photo process, taken together with some simple optical relations; that the performance of eye, film, and some pickup tubes approach sufficiently close to ideal performance to suggest a unified approach to many of their current problems and that such an approach leads to simplifying concepts.

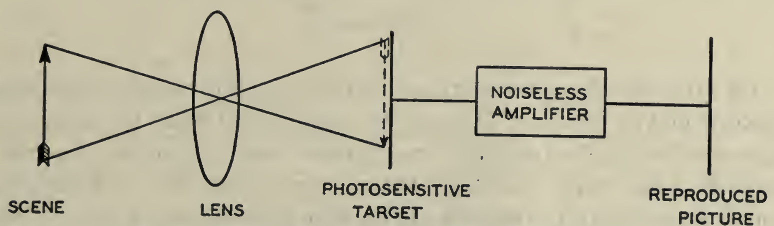

FIG. 1. Essential parts of a picture pickup system.

Ideal Picture Pick-Up Device.—Fig. 1 shows the essential parts of a system for picking up and reproducing a picture. Attention will be centered on the target of the pickup device, and, in particular, on one picture element of that target. A picture element is here taken to be an element of area of arbitrary size, not necessarily the smallest resolvable area. Let that element have a length of side h, and absorb an average number N, of quanta in the exposure time allowed. The absorption of each quantum will give rise to a separate event such as the release of an external photoelectron, or an internal photoelectron or the dissociation of a molecule. These are uncorrelated chance events. For this reason, the average number N has associated with it fluctuations whose root mean square magnitude is

the square root of the average number. Thus, if N is taken to be the measure of the signal, $N^{1/2}$ is a measure of the smallest discernible difference in signal. In particular, the ratio

$$\frac{N}{N^{1/2}} = N^{1/2}$$

is the signal-to-noise ratio. We may write, therefore,

$$\text{Signal-to-noise ratio} \equiv R = N^{1/2} \tag{1}$$

and the geometric relation:

$$\text{Scene brightness} \equiv B = \text{constant } \frac{N}{h^2}. \tag{2}$$

Combination of Eqs (*1*) and (*2*) yields:

$$B = \text{Constant } \frac{R^2}{h^2}. \tag{3}$$

Eq (*3*) is the characteristic equation for the performance of the ideal picture pickup device. It must be emphasized that Eq (*3*) is not concerned with the particular mechanism used to generate a picture so long as full use is made of all the absorbed quanta. For this reason, it is meaningful to inquire whether the performance of such diverse mechanisms as the eye, film, and pickup tubes can all be described by the same characteristic equation.

Eq (*3*) defines the scene brightness B required to transmit a picture having a signal-to-noise ratio R associated with picture elements of linear size h. It says that the scene brightness must be increased as the square of the signal-to-noise ratio demanded, and as the square of the number of lines in the picture, the number of lines being proportional to $1/h$.

The constant term on the right-hand side of Eq (*3*) contains, among other parameters, the quantum efficiency of the photo process. It is this quantum efficiency* alone which sets the performance range of the ideal pickup device. The complete constant term will be given later. For the moment, it will be useful to examine a plot of Eq (*3*).

---

* If the term "ideal pickup device" were to receive its full emphasis, the quantum efficiency of the photo process should, of course, be taken to be 100 per cent. The emphasis here, however, is on the complete utilization of all absorbed quanta rather than on the absorption of all incident quanta.

Fig. 2 is a plot of Eq (*3*) for several values of scene brightness. Fig. 2 shows that the signal-to-noise ratio increases linearly with the size of picture element considered. In particular, there is a smallest element which is determined by the smallest signal-to-noise ratio that can be observed. The smallest element would be called the limiting resolution. The smallest observable signal-to-noise ratio has often been taken to be unity. Actually, by virtue of its statistical origin, the smallest observable R is a function of how often one prefers to have his observations correct. This much is verifiable both from analysis and from the use of physical instruments as observers.

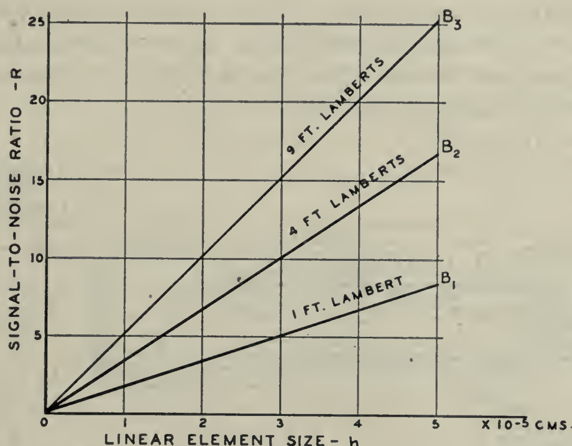

FIG. 2. Performance curves for an ideal picture pickup device.

For a human observer, tests[1] have been made which suggest a threshold value of R in the neighborhood of five. Whatever this threshold is, one may draw on Fig. 2 a horizontal line whose intersections with B_1, B_2, and B_3 mark the limiting resolutions for the several scene brightnesses.

The complete form of Eq (*3*) may be readily obtained[2] from well-known optical relations and is

$$B = 2.8 f^2 \frac{R^2}{th^2\theta} 10^{-13} \text{ ft-L.} \tag{4}$$

Here f = the f/value (numerical aperture) of the lens
t = exposure time (seconds)

θ = quantum yield of the photo process (θ = 1 means 100 per cent quantum efficiency)
h = length of side of element (cm)
1 lumen = 1.3×10^{16} quanta per sec (average for white light).

If one takes the hyperfocal distance as a measure of depth of field, the performance of the pickup device is completely specified by Eq (4) together with the relation.[3]

$$\text{hyperfocal distance} \doteq \frac{FD}{2h} \tag{5}$$

where F = focal length of lens
D = diameter of lens.

Complete specification means that one selects the desired values for the hyperfocal distance, exposure time, signal-to-noise ratio, angle of view, and size and number of picture elements, and from them computes the scene brightness required.

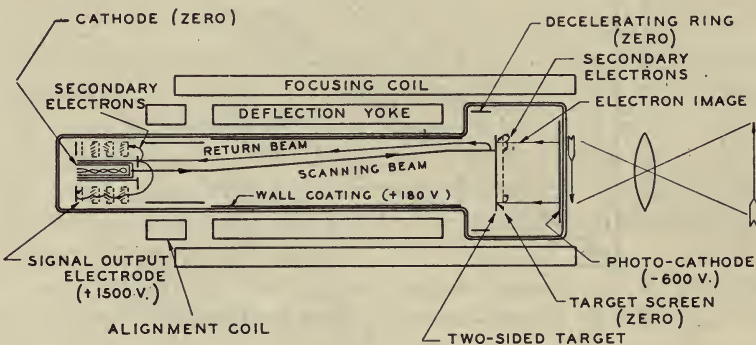

IMAGE ORTHICON
FIG. 3. Image orthicon (schematic).

The scale factors for the curves of Fig. 2 are based on Eq (4) with the choice of $f = 2$, $t = 1/30$, $\theta = 1$. These curves show what may be expected from an ideal device with 100 per cent quantum efficiency.

Television Pickup Tubes.—No operable pickup tube has yet been reported which completely fulfills the properties of the ideal pickup device. The effective exposure time of the image dissector,[4] or other nonstorage devices, is limited to a picture element time and such devices are correspondingly insensitive. The performance of the iconoscope[5] and orthicon[6] is limited by noise currents in the television amplifier rather than by the smaller noise currents inherent in the

primary photo process. The image orthicon[7] (Fig. 3) goes a long way toward removing this limitation in so far as the high light signal-to-noise ratio of its output is, within limits, determined by the signal-to-noise ratio in the primary photo process. It is handicapped, as are the other storage-type tubes, mainly by having as much noise in the low light portions of a picture as in the high lights. Eq (*4*) may, however, be used to describe the performance of the image orthicon if signal-to-noise ratio is interpreted to mean the signal-to-noise ratio in the high light portions of the picture.* The quantum yield of the primary photo process is about 0.01 and the noiseless amplifier to be compared with Fig. 1 is its electron multiplier.

Photographic Film.—One does not readily think of film as having a signal-to-noise ratio. Yet, the separate grains randomly situated in film are immediately comparable with the separate and randomly spaced electrons in the scanning beam of a television pickup tube. And, in fact, a number of recent objective measurements as well as analyses of graininess have led to the expression[8]

$$\Delta D \doteq \frac{\Delta T}{T} = \text{constant} \times a^{-1/2} \qquad (6)$$

where ΔD and ΔT are the rms deviations in density and transmission, respectively, of an area a of film.** With the notation of Eqs (*1*) and (*2*), $\frac{\Delta T}{T} = R^{-1}$ and $a^{-1/2} = h^{-1}$ and one may write for film

$$R = \text{constant} \times h. \qquad (7)$$

The value of this constant is proportional to the reciprocal grain diameter. There is good evidence that, for the same type of photographic grain, the film speed is proportional to the grain area. The last two statements combined with Eq (*7*) give

$$B = \text{constant}\,\frac{R^2}{h^2}$$

* The beam current used to scan the target must be sufficient to discharge the high light portions of the picture. Under these conditions, the signal-to-noise ratio inherent in the beam is approximately that of the high lights. The same beam current, however, scans the low lights and adds appreciable noise over and above the noise inherent in the low lights.

** Eq (*6*) obviously cannot hold for values of a in the neighborhood of and less than the grain size. Krevald and Scheffer[9] and Raudenbusch[10] have observed such departures and more recently Jones and Higgins[14] have reported them. The problem is further involved by a range of grain sizes in any one film.

just as for the ideal device (Eq *3*). One can accordingly use Eq (*4*) to describe the performance of film with the understanding that the ratio R^2/h^2 is characteristic of film with a given average grain diameter and changes in R^2/h^2 are obtained by use of other films with different average grain diameters. The quantum yield is the reciprocal of the number of incident quanta required to make a grain developable* and from published statements[11] is in the neighborhood of 0.001. The noiseless amplifier to be compared with Fig. 1 is the complete development of a silver grain after only a few silver atoms have been formed by the action of the light.

Human Eye.—Eq (*4*) is not immediately applicable to the human eye because there is no way of directly measuring the signal-to-noise ratio that the brain perceives. It is necessary, therefore, to replace signal-to-noise ratio by its equivalent in terms of minimum discernible contrast in the test object viewed.** The signal-to-noise ratio R has already been referred to as a measure of the minimum discernible difference in signal. This allows one to write with reasonable assurance

$$\text{minimum discernible contrast} \equiv C = \frac{\text{Const.}}{R} \times 100 \text{ per cent.} \qquad (8)$$

To get a value for the constant, let C take on its maximum value, *viz.*, 100 per cent. This defines the constant to be equal to the minimum perceivable value of R. As mentioned earlier, the measurements of Romer and Selwyn may be interpreted to give a value of about five. Unpublished measurements by O. Schade on television pictures yield a value of three. The determination of this constant is of considerable importance in estimating the quantum efficiency of the human eye and deserves more experimental work.† For the

* Strictly, this use of the term "quantum yield" is in accord with its normal definition only if a grain is made developable by the absorption of a single quantum. If more than one quantum needs to be absorbed for this purpose, the process still may be looked upon for noise computations as the equivalent of the absorption of one quantum because the noise arises mostly from the random distribution of grains rather than from the fluctuations in rate of absorption of light quanta.

** Contrast is defined as $\frac{B_L - B_D}{B_L} \times 100$ per cent, where B_D is the brightness of a gray test object immersed in a white surrounding of brightness B_L.

† An interpretation of the experimental results of Jones and Higgins[14] in which the blending distances and signal-to-noise ratios were measured for the same films also leads to a value of about five.

present it will be included as an undetermined constant. Substitution of Eq (*8*) in Eq (*3*) gives

$$B = \text{constant}\ \frac{1}{C^2 h^2} \tag{9}$$

for the characteristic equation which the eye would satisfy if its performance were "ideal." Eq (*9*) may be rewritten with the minimum

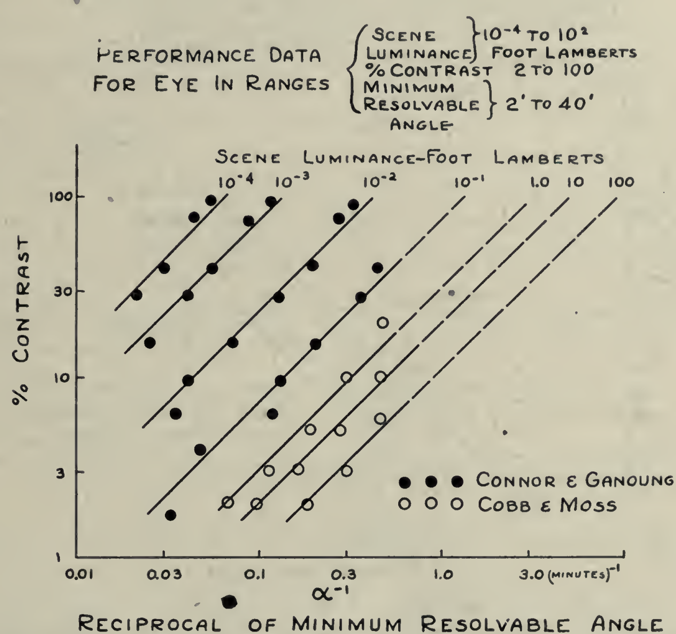

FIG. 4. Comparison of experimentally observed performance of the eye with ideal performance.

resolvable angle α in place of distance h to make it more readily comparable with published data. Thus,

$$B = \text{constant}\ \frac{1}{C^2\ \alpha^2}. \tag{10}$$

How well the performance of the eye matches Eq (*10*) may be seen from Figs. 4 and 5. Fig. 4 shows a plot[12] of C versus α^{-1} for a large range of scene brightnesses and, as expected from Eq (*10*), the data fall closely on 45-deg lines. Data in the immediate neighborhood of α = 1 minute and C = 2 per cent are omitted because these represent

limits to the performance of the eye set by other than statistical considerations. The smallest angle that the eye can resolve at high lights, for example, is set by the physical size of the retinal elements or cone structure. A more precise treatment would include, and be slightly modified by, the shape of the eye curve near its "cutoff" limits.

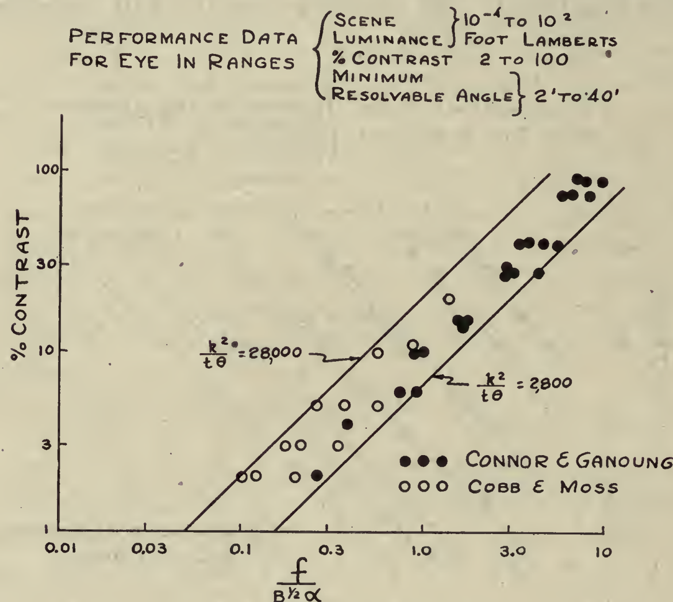

FIG. 5. Replot of data in Fig. 4.

The complete characteristic equation for the eye, from Eqs (*10*) and (*4*), is

$$B = 1.4 \frac{f^2k^2}{\alpha^2C^2t\theta} \times 10^{-2} \text{ ft L} \tag{11}$$

where α is the angle in minutes of arc subtended by a picture element at the eye and k is the undetermined constant relating C and R. Fig. 5 is a replot of the data in Fig. 4. It is a more complete test of the characteristic Eq (*11*) and shows the small range* of the factor

* If the full range of this factor is ascribed to the variation of quantum efficiency from low to high lights, one is presented in this approach with at most a ten-to-one variation in sensitivity of the eye from low to high lights as opposed to the usual statement that the dark adapted eye is 10^3 to 10^4 times as sensitive as the light adapted eye.

$k^2/t\theta$ from very low to very high lights as well as its actual value. At low lights the value of $k^2/t\theta$ is 2800. If one takes the exposure time t to be 0.2 sec, $k^2/\theta = 560$. It is known[13] that at threshold about 150 quanta (near 5300 A) must be *incident* on the eye to generate a sensation. This corresponds to about 500 quanta if white light is used. Various measurements and computations[13] of the number of quanta actually *used* in generating the sensation vary from one to 50, giving θ the range from 0.002 to 0.1 and k the range from one to 7. This range of k is to be compared with the independently obtained values of five from Romer and three from Schade.

All of the above discussion has been for the purpose of showing that the performance of the eye satisfies the same type of equation as that obtained for the ideal pickup device. The quantum efficiency, assuming $k = 5$, is about 5 per cent at low lights and about 0.5 per cent at high lights. The noiseless amplifier to be compared with Fig. 1 may be some catalytic or triggering action induced by the absorption of quanta in the retina.

General Discussion.—The classes of picture pickup problems that have received frequent attention are:

(*1*) Specification of the performance of any one pickup device;

(*2*) Comparisons of the performance of two pickup devices of the same kind, or of different kinds;

(*3*) The setting of standards of performance for pickup devices that would "satisfy" the human eye.

The particular problems to be discussed here are intended only to be representative, rather than exhaustive.

Sensitivity.—The simplest test for the relative "sensitivities" of two devices is accomplished by observing the lowest scene brightnesses at which they can still record a picture. This type of test is immediately subject to the questions: Was the exposure time the same for the two devices? What were the relative lens speeds used? What were the relative picture sizes? While these are obvious questions, there is no essential reason to pause here. The further questions of relative angles of view, numbers of picture elements and signal-to-noise ratios are of equal importance. In brief, the comparison of the sensitivities of two devices is not meaningful until the devices and their transmitted pictures are completely specified. But complete specification, as pointed out earlier, means that the quantum efficiency of the primary photo process is the only parameter that can vary the range of performance of an ideal device. And

accordingly, the quantum efficiency is the measure of sensitivity. Not all devices, however, are ideal. For this reason, a more general figure of merit, based on Eq (*4*) is here proposed. The figure of merit is proportional to the reciprocal of the total light flux required to produce a picture of specified signal-to-noise ratio and resolution in a specified exposure time. The figure of merit is

$$\frac{f_2}{BA}$$

where f is the numerical aperture of the lens, B the scene brightness, and A the area of target. If the performance of the device is ideal, the figure of merit becomes also a measure of its quantum efficiency.

It is recognized that the signal-to-noise ratio of a given picture is not a readily accessible parameter and that there is no general agreement on a measure of resolution. The evaluation of sensitivity, however, can be no more accurate than the knowledge of these parameters. It is of interest to apply the figure of merit to the interpretation of several familiar problems.

Film Speeds.—Consider the range of film speeds advertised. For the most part, these are films of the same quantum efficiency but different grain size* and, for the most part, the essential sensitivity performance of these films is the same. A simple example will make this clear. Two films, A and B, are rated at the relative speeds of one and four, respectively. Their quantum efficiencies are equal and the average grain area of B is four times that of A. Normally, one might say that B can pick up a scene with one-fourth the light required by A. While this statement is true, it is misleading. Suppose one wants the same resolution and depth of focus in both pictures. This would mean a film area of B four times as large as A to match resolutions and consequently a lens for B stopped to twice the numerical aperture (f/number) of the lens for A to match depth of focus. The result is that both films require the same scene brightness to transmit the same picture—a result which could have been anticipated from their equal quantum efficiencies or from their figures of merit evaluated for the same transmitted picture quality.

Comparison of Eye and Film.—An interesting application of the figure of merit is to the taking and viewing of motion pictures.

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* The relative speeds of Super XX and Eastman High Resolution plates are in the ratio of about 10^4 to 1. The relative grain areas are in the ratio of about 10^3 to 1.

For obvious reasons, the quality of the motion picture (signal-to-noise ratio and resolution) is aimed at equaling or exceeding the quality of picture which the eye can transmit at the brightness of the motion picture screen. For equal quality one can anticipate that the figure of merit for the eye would be at least a factor of twenty better than for film based on relative quantum efficiencies. But, in so far as film aims at better quality and attempts to compensate for some of its limitations by projecting pictures at a higher than unity gamma, an additional factor can be expected in favor of the eye.

Table 1 gives approximate values for f, B, and A to be associated with the camera that takes the pictures and the eye that views them.

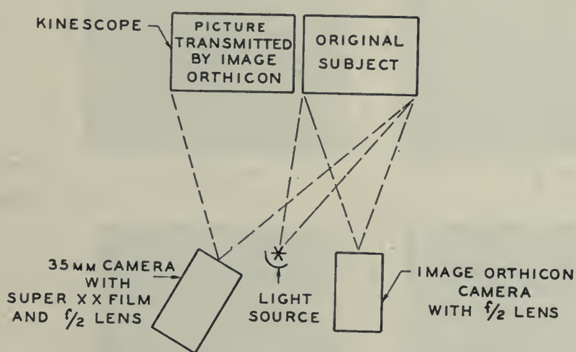

FIG. 6. Setup for comparison of low light performance of Super XX film and an image orthicon.

The area of target used for the eye is that area of retina occupied by the motion picture at a 4:1 viewing distance. The figure of merit for the eye is seen to be 250 times that for film.

TABLE 1

		B, Ft-L	A, In.^{2}	$\frac{f^2}{BA}$
Eye	2.5	10	0.03	20
Film	2	100	0.5	0.08

Comparison of Film and Television Pickup Tubes.—Fig. 6 shows the setup for comparing the low light performance of Super XX film and an image orthicon. The original subject was illuminated with an ordinary 40-w bulb attenuated with neutral filters. The television camera was focused on the subject alone and its picture was

reproduced on a receiver located alongside the subject. The 35-mm camera photographed simultaneously the original and reproduced pictures. Both cameras used $f/2$ lenses and an exposure time of $^1/_{30}$ sec. Fig. 7 shows the results. Only in the first exposure, at 2 ft-L brightness of the subject, do both original and reproduced pictures

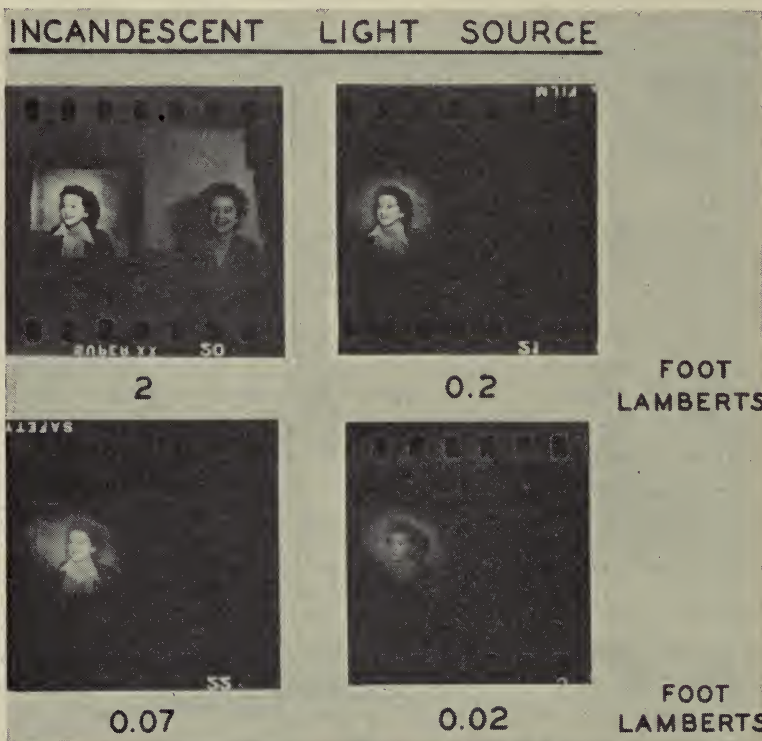

Fig. 7. Comparison of low light performance of Super XX film and an image orthicon. (Image orthicon picture is on the left of each frame.)

appear. At 0.2 ft-L only the picture reproduced by the television camera is present. And, in fact, the television camera continues to transmit a picture even at 0.02 ft-L which is the brightness of a white surface in full moonlight.

One interpretation of this test is that the image orthicon is 50 times as "sensitive" as Super XX film because it can transmit a picture with $^1/_{50}$th of the light required by the film. The present paper argues

against this interpretation and sets the factor at ten. This is based on the fact that the area of target (photo-cathode) used by the image orthicon was five times the area of the 35-mm film frame. If the cameras were to be set up to transmit the same picture with the same angle of view and depth of focus, the lens on the image orthicon would have to be stopped to $5^{1/2}$ times the numerical aperture of the lens for the 35-mm camera. The threshold scene brightnesses would then be in the ratio of 10:1.

Graininess and Signal-to-Noise Ratio.—An excellent survey of the extensive history of the problem of specifying the graininess of film has recently appeared by Jones and Higgins.[8] In this paper and in a second one[14] they undertake to compare two general methods of measuring graininess. Method I, which they describe as a psychophysical measurement, records the distance from the observer at which the grainy film appears to blend into a uniform surface. (After introducing an observer for his special virtues as a measuring instrument, he is ushered part way out again by the device of normalizing his results with a standard test chart.) Method II is an objective measurement of the transmission or density fluctuations of the film using scanning apertures of various sizes. Broadly, Jones and Higgins argue (*1*) that the objective measurements should match the "blending distance" measurements in order to be considered valid; (*2*) that the two types of measurements do not match; and (*3*) that a major discrepancy is that the blending distance measurements tend to *decrease* at large densities while the objective measurements tend to *increase*.

In contrast to the above, the present paper would argue that the two types of measurement, I (by the eye) and II (by a scanning aperture), should, so far as the eye and film satisfy the same physical equations derived for an ideal device, show good* agreement. A large part of the discrepancy noted above under (*3*) is removable when reference is made to Fig. 4. Here it is seen that in the range of 0.1 to 10 ft-L the discrimination of the eye for small contrast differences varies by about five to one. This would correspond to a five-to-

* A precise correlation between eye and instrument observations must, of course, take into account the detailed performance of eye and film near their limiting resolution—performance which both for eye and film is determined more by the finite size of its mosaic elements than by statistical fluctuations. The significance attached to precise visual observations, however, should be tempered by the known large spread of eye characteristics from individual to individual.

one ratio of blending distances for the same film viewed at a brightness of 10 and at a brightness of 0.1 ft-L. Because the visual observations of blending distance are made with a fixed source brightness attenuated by films of varying density, the resulting blending distance measurements are a product of the graininess properties of the film and the contrast discrimination properties of the eye as a function of scene brightness. When the latter term is separated out, the graininess versus density measurements by the two methods (observer and instrument) show relatively good agreement.

A further rough confirmation may be obtained by reference to some "blending distance" measurements of Lowry[15] in which a *constant viewing brightness* was preserved. These showed about a factor of two *increase* in graininess for a variety of films in the range of densities from 0.2 to 1.0. This increase is in good agreement with the objective (large aperture) measurements of Jones and Higgins[14] shown in their Fig. 16.

It is worth commenting briefly on another item emphasized in the second paper by Jones and Higgins.[14] The concept of the "effective scanning area" used by the eye in evaluating graininess is introduced. This is thought to be a useful concept particularly because the results of objective measurements, using different scanning aperture sizes, suggest the possibility of matching visual observations with small apertures rather than large apertures.

Arguments, similar to the above, were at one time current in evaluating the "noise" in a television picture. It was often remarked that it was only the high-frequency noise that was objectionable. This would correspond, for example, to selectively emphasizing the observations of graininess of film obtained with small scanning apertures (either retinal or instrumental). It is a relatively simple experiment in a television system to increase the effective scanning aperture several fold, either by reduction of pass band or by defocusing the kinescope spot. Such aperture changes are accompanied by large changes in total noise power as viewed on the kinescope. Yet the effect on visibility of noise of cutting out the high-frequency noise components is small compared with the same changes in noise power distributed uniformly over the noise spectrum. This latter statement is borne out by the curves in Fig. 7. In brief, the visibility, or annoyance, of noise must be assessed over the full range of picture element sizes from elements at the limiting resolution of the eye to the largest element, which is the picture itself considered as a unit.

Resolution.—The most frequently used, because it is the most easily observed, specification of resolution is the finest detail that a system can resolve. This is true for film, pickup tubes, the eye, and optical lenses. In general, this specification is satisfactory if it is appreciated that the limiting resolution itself has only narrow utility and that the limiting resolution is more an indirect measure of what detail is *well resolved* by the system. The "well-resolved" detail may be two to four times coarser than the finest detail. And in the judgment of picture quality, the eye attaches little weight to the picture elements in the neighborhood of limiting resolution.

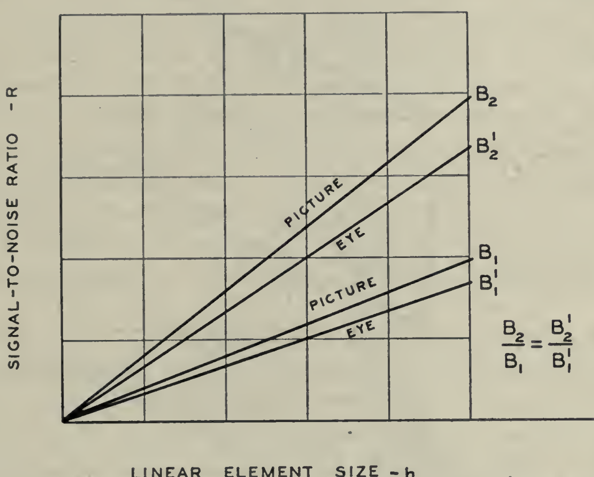

FIG. 8. Dependence of scene brightness on reproduction brightness.

One illustration of the confusion caused by the use of limiting resolution is the comparison frequently made between the resolution of motion picture film and of a television system. The *limiting resolution* of film is compared with the "*cutoff*" *resolution* of a television picture. The picture detail at the "cutoff" resolution of a television system, however, as limited by the amplifier pass band, has at least the possibility of being clearly resolved. It is misleading to attach the same weight to this type of resolution as is attached to the *limiting resolution* of film. It would be nearer a true evaluation if the resolution of film were specified at that number of lines at which film matched the signal-to-noise ratio of a television system at its "cutoff." Such a

comparison would place the resolution of 35-mm motion picture film, normally quoted at a limiting resolution of 1000 to 2000 lines, nearer to the resolution of a 500-line than a 1000-line television picture.

In general, the specification of the signal-to-noise ratio that a picture pickup device can transmit at an intermediate resolution is a more accurate and significant specification, not only of resolution, but also

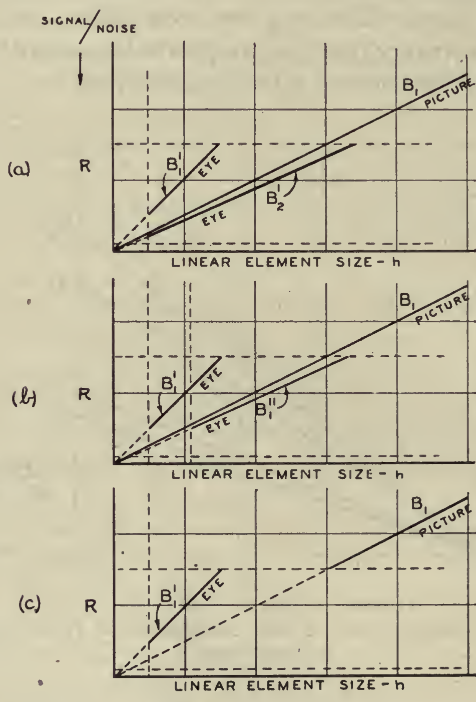

FIG. 9. (*a*) Noise reduction by lowered reproduction brightness; (*b*) Noise reduction by increased observer distance; (*c*) Noise reduction by bandwidth reduction.

at the same time of the half-tone discrimination of the device, than is the specification of limiting resolution.

Satisfying the Human Eye.—Only one problem, that of presentation brightness, will be discussed here. Fig. 8 shows the signal-to-noise ratio curves of a picture taken at scene brightness B_1, and viewed by the eye at presentation brightness B_1'. The viewed picture is assumed to be "noise free" and accordingly the B_1 curve lies above

the B_1' curve. If, now, the presentation brightness is increased to B_2', the original scene brightness must also be increased, other things being constant, by the same factor to B_2' in order to match the increased discrimination of the eye. These considerations are significant because both motion pictures and television pictures aim at higher presentation or screen brightness.

The converse of the above operations makes an interesting test. Given a grainy motion picture or a "noisy" television picture, the most effective way of eliminating the fluctuations with the least cost to picture detail is to interpose a neutral filter between the eye and the picture. The discrimination of the eye is thereby readily reduced below the fluctuation limits of the picture. At the same time, the picture is shifted to a portion of the eye characteristic which shows higher apparent contrast and thus partially compensates for the loss of brightness. Fig. 9 shows schematically the effect on picture detail of three ways of trying to eliminate "noise": reduction of picture brightness, increase in viewing distance and reduction of bandwidth of the picture. The last-named operation is peculiar to a television system and, while it reduces the total noise in the system, has little effect on the visibility of noise until an extremely coarse picture is obtained.

The curves B_1 are the signal-to-noise ratio characteristic of the picture. The curves B_1', B_1'', B_2' are the signal-to-noise ratio characteristics of the eye at the brightnesses B_1' and B_2'. In order that the fluctuations in the picture not be observed by the eye, the signal-to-noise ratio of the picture should be above B_1', B_1'', or B_2'. The limits of performance of the eye are shown by the three dotted lines. They mark out the minimum area that the eye can resolve by virtue of its cone structure, the minimum signal-to-noise ratio that it can perceive, and the maximum signal-to-noise ratio it can generate corresponding to the Weber-Fechner limit of 2 per cent brightness discrimination. The "cutoff" characteristics of the eye are shown as idealized sharp breaks to simplify the argument.

Starting with a noisy picture, that is, B_1' lying above B_1 as in Fig. 9*a*, there are several formal operations that can be performed to get rid of the noise, that is, to insure that *all parts* of B_1 lie above the eye curve. Each of these operations corresponds to a physical operation and each affects the observed picture detail differently. In Fig. 9*a* the eye curve B_1' is transformed into B_2' by a change of ordinate scale factor. This corresponds to interposing a neutral filter at the eye.

The finest detail observable is still at the "cutoff" limit of the eye. In Fig. 9*b*, the eye curve B_1' is transformed into B_1'' by a change of abscissa scale factor. This corresponds to backing away from the picture. Although the finest observable detail remains at the "cutoff" of the eye, this "cutoff" now corresponds to coarser detail in the picture. In Fig. 9*c*, the pass band of the amplifier through which the original picture is transmitted is reduced to the point where the picture fluctuations are below the Weber-Fechner limit. This is an expensive way to remove noise—expensive in picture detail.

A final aspect of the significance of presentation brightness arises in the comparison of the low light performance of a man-made device with that of the human eye. Assume, for example, that the man-made device is as sensitive as the eye. If one picks up a scene whose brightness is 0.1 ft-L and views the reproduction at a presentation brightness of 10 ft-L, noise should be visible in the reproduction while it was not visible in the original scene. The higher presentation brightness gives the eye an unfair advantage. A more valid procedure would match the presentation brightness of the reproduction with the brightness of the original scene.

Visual Noise.—The phrase "signal-to-noise ratio of the eye" has been used frequently in the preceding discussion. One might expect to be able to "see" these fluctuations just as one sees the graininess of film or the noise in a television picture. The writer is convinced that such fluctuations are observable* particularly at low lights around 10^{-4} ft-L. A white surface then takes on a grainy appearance not unlike that of motion picture film. The observations in more detail are: in complete darkness little or no fluctuations are detectable, a fact which attests the substantial absence of local noise sources in the eye. Near threshold brightnesses, large area, low amplitude fluctuations appear. At higher brightnesses these fluctuations increase in amplitude and decrease in size. In the neighborhood of 10^{-2} ft-L the fluctuations tend to disappear and a white surface takes on a "smooth" appearance and remains so at normal brightness levels. A secondary observation is that low-level blue light appears distinctly more grainy than low-level red light.

The last observation, together with known data on dark adaptation, fits in well with the assumption of a gain control mechanism in the eye. This gain control, just as the gain control in a television

* See also DeVries.

receiver or the lamp brightness used for film projection, does not alter the signal-to-noise ratio but does alter the visibility of noise by presenting the picture at a higher or lower brightness level. Thus, at high scene brightnesses, the gain control in the eye may be turned down to the point where the fluctuations are just not visible. (The sensitivity of the eye is apparently high enough to afford this luxury.) If one suddenly reduces the scene brightness, the gain control is still momentarily set at a low value and the picture is dim or not visible. As the gain control resets itself at a higher level, the picture appears to get brighter. This corresponds with the experience of dark adaptation. At these low light levels (10^{-4} ft-L) one has only to assume that the gain control is set high enough to make the fluctuations visible.

To account for the observation that low-level blue light appears to have more fluctuations than low-level red light, the gain control mechanism can be assumed to be set higher for blue than for red. This is not as "*ad hoc*" as it may appear. The reason is that, although at low-light levels* blue appears brighter and grainier than red, they both present the same resolution to the eye.[16] And since the resolution is determined by signal-to-noise ratio, this is in agreement with the assumption of a gain control that varies presentation brightness but not signal-to-noise ratio.

Acknowledgments.—The writer would like to acknowledge, without committing the acknowledged to the conclusions presented above, his indebtedness to Dr. D. O. North and Dr. G. A. Morton of these laboratories, and O. H. Schade of the Victor Division of RCA for many profitable discussions of the subject of this paper.

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THE HIGH COST OF POOR PROJECTION*

CHARLES E. LEWIS**

Summary.—*Only five per cent of the capital invested in the motion picture industry is in studios and distribution facilities. Ninety-five per cent, aggregating a total of $1,900,000,000, is invested in motion picture theaters and their equipment. This staggering investment is in the hands of the exhibitor. He needs technical advice.*

The Society of Motion Picture Engineers has built up the necessary body of technical knowledge; but the exhibitor cannot follow the Society's work in detail because he is equally harassed with many theater problems. The Society should arrange to segregate and collect those items of information appearing throughout its JOURNAL *which would be of direct help to him. These could then be published in handy reference form for dealing with theater projection problems. There is no other single aid to good projection that could be more helpful.*

It has very often been said that the process of putting a motion picture before the public involves a long chain of operations. Each link is equally indispensable to the final result. A broken chain is a broken chain no matter where the break occurs. This Conference has heard some highly valuable and important papers that deal with chemical analysis of developing solutions. That is one link. The decision of a theater owner or manager about signing a check for improvements in projection equipment is another—and equally important.

Weakness anywhere in the chain is expensive to the industry. As for poor projection, the industry pays for that in at least three different ways.

On the question of what relationship exists between good projection and box-office receipts, *Showmen's Trade Review* recently conducted a survey. Selected groups of representative theater managers were queried. These are the men who are on the spot and ought to know. In the opinion of 80 per cent of those who answered, an unquestionable increase in box-office revenue follows improvements in projection or sound equipment.

* Presented May 9, 1946, at the Technical Conference in New York.

** Publisher and Editor, *Showmen's Trade Review*, New York.

The industry loses this increase in revenue wherever projection is neglected.

There is an additional loss, however, which is not confined merely to those theaters that are neglectful. The best equipment and the best care cannot get good projection out of mutilated prints. The industry suffers a further box-office loss through the carelessness of those theaters which neglect their equipment to the point where it damages prints.

A third loss to the industry results from shortening the life of the prints.

Good projection, therefore, is a matter of practical financial concern to everyone who draws his livelihood from this industry. The cost of poor projection is a direct or indirect tax on all of us, and a drain that helps to limit appropriations for research and development.

The practical questions would seem to be: (*1*) What is good projection? (*2*) How can we get it?

Good Projection—It is not the place of an exhibitor to tell the Society of Motion Picture Engineers what good projection is. So far as the exhibitor is concerned, good projection is that which conforms to the standards this Society has been so patiently elaborating for many years.

Good projection is that in which the brightness at the center of the screen is between 9 and 14 ft-L when the projector is running with no film in the gate. I do not say this. Your Committee on Standards says so. And in this connection I hope it will not be out of place to add a word, from the exhibitor's point of view, with respect to the very valuable work done by your Film Projection Practice Committee. It would, in my opinion, be a great service to the industry if, now that the war is over, the activities of the Film Projection Practice Committee could be resumed.

It is you—the Society—who tell this industry what good projection is. But when the Society of Motion Picture Engineers establishes standards for the motion picture industry there still remains a vital practical problem. It is the problem of keeping that information effectively at the elbow of a critically important class of men who have urgent need of it—and I propose to confine this discussion to that one link only—the exhibitor—the man who has to make up his mind about signing the check.

That man needs help. It is easy to point out that the SMPE puts invaluable technical guidance at his disposal. But is that poor,

harassed man also to become a member of the American Society of Heating and Ventilating Engineers, the American Institute of Architects, the Illuminating Engineering Society, and the American Institute of Accountants? All these organizations no doubt could give him information that would be of great value to him. He is also expected to be an expert on advertising, exploitation, and employee relations, and on the supervision of plumbing.

The Exhibitor.—The exhibitor is the forgotten man of this industry. Yet his stake in it is vastly greater than that of all other branches combined. Recent figures of the Motion Picture Producers and Distributors Association show a total sum of 125 million dollars invested in American studios, an additional 25 million dollars investigated in American distribution facilities, and the tremendous total of one billion, nine hundred million dollars invested in American motion picture theaters.

That is to say, approximately 95 per cent of all the capital in this industry is in theaters and their equipment. This stupendous aggregate of capital value is in the hands of the exhibitor—the forgotten man.

With respect to projection, the exhibitor has advice at his disposal. The projectionist is another very important link in the chain. The exhibitor can secure invaluable technical advice from his projectionists. Service inspectors and supply dealers also can and do advise him. But the trouble is he is the man who must make the decision. The advice he gets from these sources is often conflicting. And he must keep in mind that while the advice is almost invariably honest, it is not always disinterested. He needs some little information of his own—some standards of reference—to help him decide.

It is true that in considering what to do about conflicting advice, the exhibitor can turn to Vol 43 of the JOURNAL of the SMPE and find there what his screen brightness ought to be according to the Committee on Standards. If he reads carefully through Vol 39 of the JOURNAL he will find out that he ought to install a voltage regulator if line variations exceed $\pm$ 3 per cent. Vol 36 will tell him that his screen width should equal one-sixth the distance from the screen to the rear seats, and so on.

But probabilities are that he does not have a file of the JOURNAL, and that if he did he could not find what he wanted when he needed to find it.

Yet, he is the man whose decisions are final. He signs the checks.

He and no one else, in the great majority of theaters, determines what shall be done and what left undone.

Getting Better Projection.—This brings me to the practical suggestion I would like to place respectfully before you for your consideration. Can the Society arrange to segregate and collect those items of information appearing throughout the JOURNAL which would be of direct help to the exhibitor, and to publish them in a form which the average exhibitor could use as a small reference encyclopedia to his projection problems? Or if the Society is not willing to undertake this work, will you permit others to do it?

You have compiled technical data about projection that is of the utmost practical value. The highest kind of skill and competence and an immense amount of labor have gone into building up this body of technical knowledge.

I can think of no one single aid to good projection that would be more helpful than to put this mass of expert information into the hands of the exhibitor in a form in which he can make effective use of it.

FACTORS GOVERNING THE FREQUENCY RESPONSE OF A VARIABLE-AREA FILM RECORDING CHANNEL*

M. RETTINGER** AND K. SINGER**

Summary.—*This paper is an analysis of the essential factors governing the most desirable dynamic frequency response of an RCA variable-area sound recording channel, and includes a study of the most suitable location of the various equalizers employed in the system. It consists of five parts:*

(*1*) *Derivation of equalization characteristic for the RCA sound-on-film recording channel;*

(*2*) *Review of effort equalization and of relative spectral energy distortion in electronic compressors;*

(*3*) *Recommended recording channel equalization;*

(*4*) *Experimental work;*

(*5*) *Conclusions.*

By dividing the paper into these interrelated parts, the different phases of the subject can be studied more conveniently than if no such subdivisions were made. Also, the fifth part contains the results and recommendations reached in the first four parts.

PART 1

Derivation of Equalization Characteristic for the RCA Sound-on-Film Recording Channel.—In the field of sound recording, as in every other branch of modern industry, effort is constantly being made to improve the product. Operating conditions are frequently checked and the results critically examined to learn whether any change in equipment or technique would provide more natural or more effective sound recording.

The frequency response of sound recording channels has been determined largely by empirical methods. These methods will probably continue in use for some time, at least to the extent of providing the sound director with a means of controlling the finer adjustments to suit his judgment.

A study of the essential fixed factors determining the equalization characteristics of an RCA variable-area sound recording chan-

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** RCA Victor Division, Radio Corporation of America, Hollywood.

nel has been made. The purpose of this study was to observe how closely the calculated characteristics came to agreeing with those determined by empirical methods and to determine whether the results could be improved by replacing the empirically determined characteristics by those obtained by calculation.

The electrical characteristics of a high-fidelity sound recording system are as important as are those of the physiology and psychology of speech and hearing. There are also a number of acoustic and electroacoustic factors which must be critically examined.

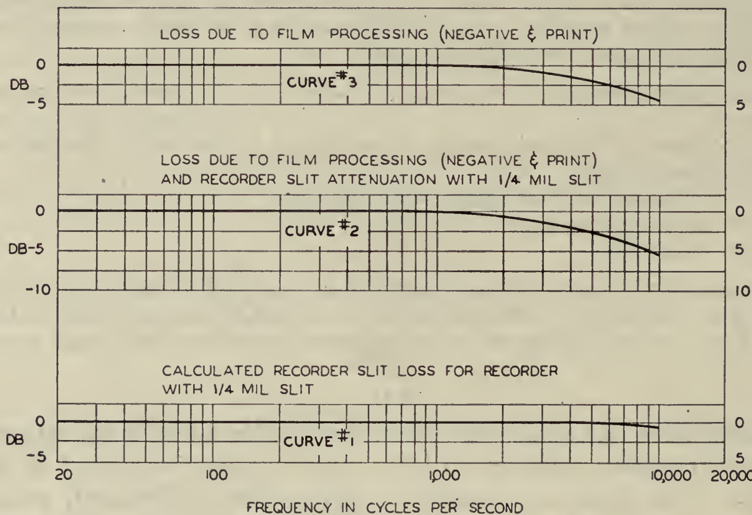

Fig. 1A.

The following discussion deals with each of the important phases of sound recording and reproduction, with which we are concerned, in order to ensure satisfactory results in a typical theater.

We will first discuss the factors which determine the optimal frequency response of an RCA variable-area sound-on-film recording system.

Curve 1 of Fig. 1A shows the high frequency loss owing to a $^1/_4$-mil recorder slit which is currently used in all of our studio-type recorders.[1]

Curve 2 of Fig. 1A illustrates the loss of high frequencies caused by film processing and recorder slit attenuation. The curve is not based on theoretical calculation, but represents experimental results. The

recorder slit was $^1/_4$ mil in width. The film processing losses include not only the so-called negative processing losses, but also the printer and print losses. Ultraviolet light was used in the recording, and the film processing was carried out in a commercial Hollywood laboratory. These negative processing, printer, and print losses may be assumed as correct for standard, push-pull, and class-*B* recording. They may not be correct for all types of film, and slight deviations may occur in different laboratories.

Subtracting Curve 1 from Curve 2 of Fig. 1A, we obtain Curve 3 of Fig. 1A which represents the processing losses proper.

Fig. 1B shows the frequency response characteristic of the RCA type *MI-3121* low-pass filter for different cut-off frequencies. Ordi-

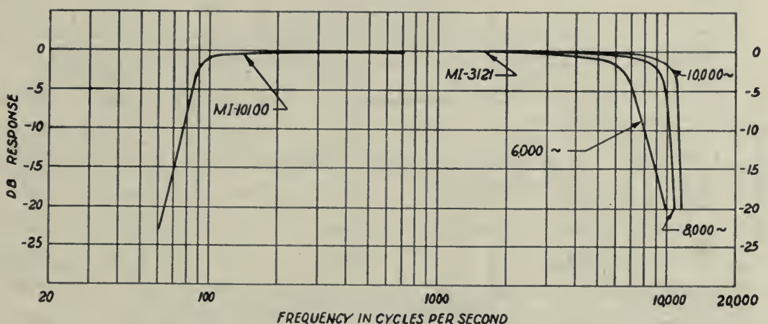

FIG. 1B. Frequency characteristics of *MI-10100* high-pass filter and *MI-3121* low-pass filter.

narily the attenuation of the filter at 6000 cycles is not considered in the derivation of the recording characteristic. The reason for this is that the attenuation is small at this frequency.

Fig. 1B also shows the frequency response characteristic of the RCA type *MI-10100* high-pass filter. This characteristic also is ordinarily not considered in the derivation of the recording characteristic. The reason for this is that in most instances, the filter characteristic has little effect in the region of dialogue equalization.

Curve 1 of Fig. 1C represents the amount of low frequency accentuation caused by the reproducing level being (on the average) 5 db above normal speech level which is the level employed by a person in somewhat noisy surroundings. This increase in level is occasioned by noises from the audience and other sources in the theater; the resulting low frequency accentuation is caused by the hearing char-

acteristic of the human ear. The ear sensitivity at different frequencies varies as a function of the intensity of the signal. The higher the intensity of the signal, the more sensitive the ear becomes to the low frequencies. To illustrate: Consider a 100-cycle tone and a 1000-cycle tone, each emitted from a speaker at the same intensity level, 60 db above the threshold of audibility. If the signal level for each is increased by a certain amount, 10 db, the 100-cycle tone will now sound louder to the ear, in reference to the 1000-cycle tone, than

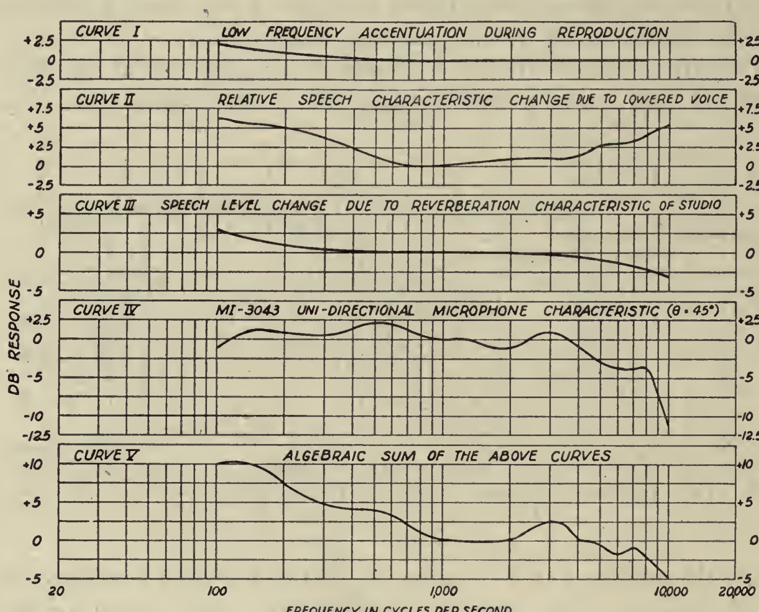

FIG. 1C.

the 100-cycle tone sounded in reference to the 1000-cycle tone before the signal level was increased.

Curve 2 of Fig. 1C illustrates the relative speech characteristic change, plotted relative to 1000 cycles.[2] Dialogue spoken on a sound stage is usually uttered at a level 5 db below the level at which it would be uttered if the surroundings were not so quiet. When a person speaks in a low tone, the low and high frequencies become relatively more distinctive as compared to a voice characteristic of normal intensity. If this low voice were reproduced at normal speech level—the level usually employed by a person situated in the more or

less noisy surroundings depicted on the screen—it would tend to sound unnatural; that is, it would sound both somewhat heavy and sibilant.

Curve 3 of Fig. 1C indicates the average accentuation of the low frequencies and the loss of the high frequencies due to the reverberation characteristic of the sound stage. Practically all acoustic materials are less absorbent for the low frequencies and become increasingly absorbent for the high frequencies. For this reason, the reverberation time at the accentuation or loss may be expressed by

$$\text{db} = 10 \log_{10} \frac{T_1}{T_0}$$

where T_1 is the reverberation time at the frequency under consideration, and T_0 is the reverberation time at 1000 cycles.

It should be noted that Curve 3 of Fig. 1C depicts the sound-level change caused only by the variation in reverberation time in the sound stage. It does not cover any losses which may be occasioned by peculiar set conditions; that is, pronounced panel resonance of a set, or room resonance of a set, or room resonance in a small enclosure. This last condition of room resonance deserves some careful consideration, particularly if the trend of providing ceilings in sets is continued. Experience has indicated that room resonance effects are the most difficult to be compensated for in rerecording. This is because usually, in the low-frequency spectrum, only a narrow frequency band is intensified, with the result that the ordinary type of low-frequency attenuation available in the rerecording channel cannot eliminate this selective emphasis without producing at the same time an unnatural effect on the character of the voice itself.

Curve 3 of Fig. 1C does not show the variation in high-frequency sound level owing to the varying reverberation time. This variation is occasioned by changes in the relative humidity of the air in the stage. The absorption of sound in the air becomes very great at the high frequencies for low relative humidities. It doubles at 6000 cycles when the normal relative humidity of 40 per cent is reduced to 20 per cent. This effect would point to the use of a variable high-frequency equalizer to compensate for varying conditions of humidity. At present no compensations for this effect are made for dialogue recording. One studio employs a variable high-frequency compensator for their music recording, to equalize the effects of varying humidity during a scoring session. The studio does not use it however,

for dialogue recording when changes of location produce as much, if not more, of a change in the high frequency transmission of sound in air. Their reason for this procedure lies in the blanket statement that "the extreme high frequencies are more important in the case of music than in speech."

Curve 4 of Fig. 1C shows the RCA type *MI-3043* unidirectional microphone response characteristic for 45-deg incidence of sound. This angle was chosen because it represents the normal pick-up angle

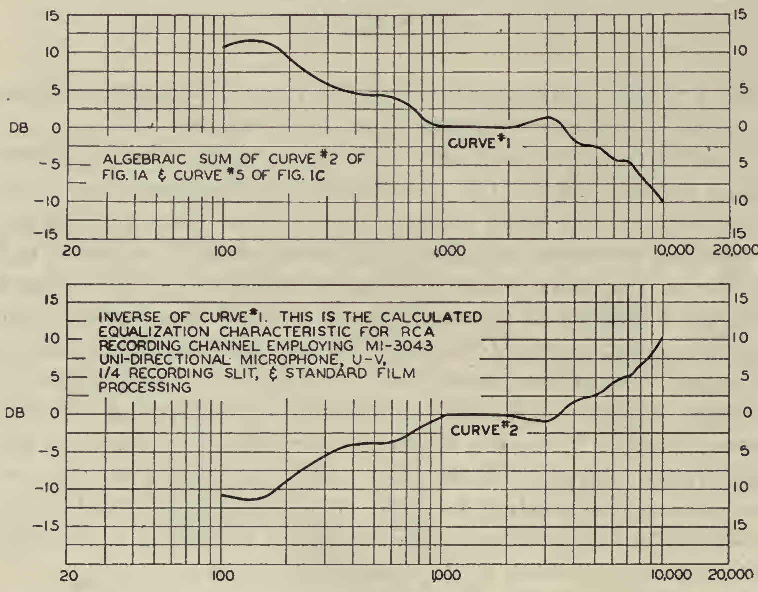

FIG. 1D.

employed in the studios. For the purpose of this discussion it is assumed that the high-frequency equalization available in the microphone is not employed. If any equalization is introduced in the microphone, a corresponding compensation must be made in the recording characteristic. Present studio practice seldom avails itself of the high-frequency equalizer in the microphone. The coil in this equalizer together with a suitable resistor, is most frequently employed to provide microphones having "matched," that is, practically identical, low-frequency response.

Curve 5 of Fig. 1C shows the algebraic sum of Curves 1, 2, 3, and 4. For the sake of convenience in the following discussion, the curve representing this algebraic sum will be referred to as the curve of "acoustic losses," in comparison with the curve representing film processing losses and slit attenuation, which will be labeled "optical losses."

Curve 1 of Fig. 1D shows the algebraic sum of the acoustical and optical losses. Curve 2 of Fig. 1D represents the theoretically derived recording characteristics and is the inverse of the summation Curve 1. This curve has been replotted on Fig. 1E (top curves)

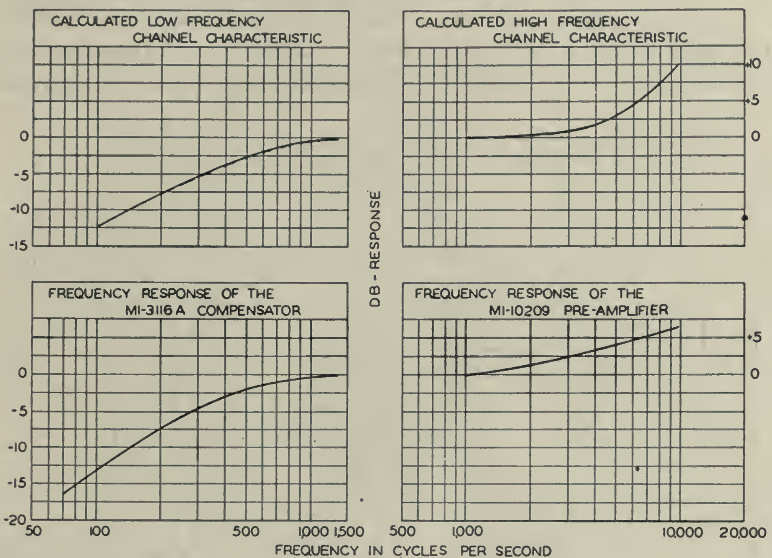

FIG. 1E.

where it has been "smoothed out," a process justified on the basis of the many variables included in the analysis. Fig. 1E (bottom right) shows the frequency response of the RCA type *MI-10209* preamplifier ordinarily used. This might indicate that the high-frequency equalization usually employed by the studios in connection with the RCA type *MI-3043* unidirectional microphone would give rise to a slight prominence of "highs" (frequencies between 1500 and 6000 cycles).

An objection to the prominence of "highs" has actually been made by one studio. On the other hand, a number of other studios claim that a slight prominence of this frequency range gives the product

"presence." It should be noted that for frequencies above 6000 cycles, the low-pass filter becomes effective.

Fig. 1E (bottom left) shows the frequency response of the RCA type *MI-3116A* low-frequency compensator, set on step 2.

PART 2

Review of Effort Equalization and Relative Spectral Energy Distortion in Electronic Compressors.—In the recording of sound on film, various types of frequency discriminations occur, some of which are compensated by equalizers in the recording channel. It is usual practice in the art thus to equalize for the frequency discrimination of the microphone, film processing, reproducer slit, *etc.*

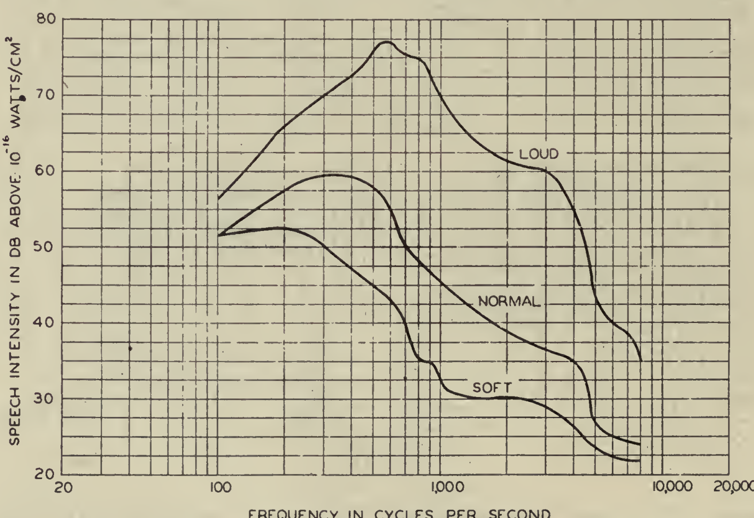

FIG. 2A. Average voice characteristics of men and women.

Another type of frequency discrimination is a variable function of the sound-level difference between normal speech levels and the voice level actually employed by the actor on the set. The correction for this latter effect has been termed "effort equalization."[2]

Another type of frequency discrimination results from the action of the compressor usually employed in the variable-area sound recording channel.[3] It is the purpose of this section to review these two effects.

In the case of "effort equalization," cognizance is taken of the fact that the voice level of the actor during recording is rather low, because a person in a very quiet surrounding, such as a sound stage, involuntarily lowers his voice. At low levels the voice characteristic shows a preponderance of both low- and high-frequency components, as compared to a voice characteristic of normal intensity. If this voice were reproduced at normal speech level, the level usually employed by a person situated in the more or less noisy surroundings depicted on the screen, it would tend to sound unnatural; that is, both somewhat heavy and sibilant.

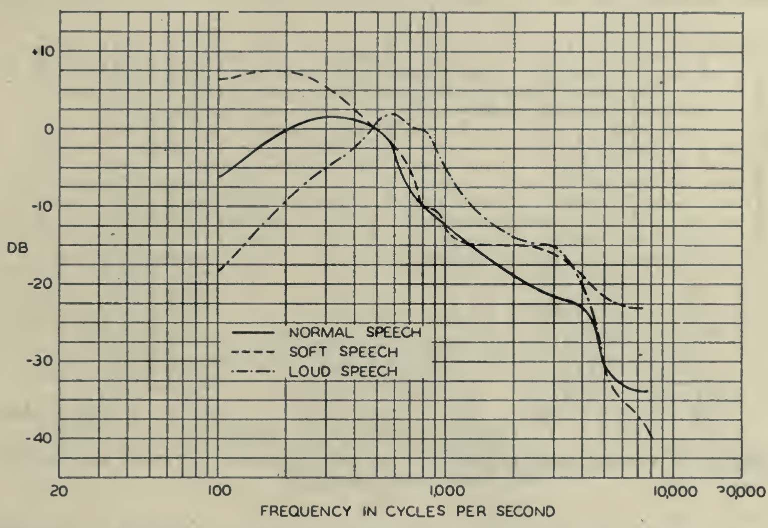

FIG. 2B. Average voice characteristics, men and women, "matched" at 500 cycles.

The only corrective measures considered in this connection are those that will compensate for the change in the voice characteristic, a change caused by the actor speaking in a lower tone than is normal. In the case where the low voice level of the actor corresponds to his normal tone of voice called for by the surroundings in which he appears, no correction is required.

Fig. 2A shows the average voice characteristics of men and women. The data for this figure were taken from the paper by Loye and Morgan. These curves were redrawn on Fig. 2B and matched at 500 cycles to show more readily that soft or low speech contains a pre-

ponderance of both low- and high-frequency components, and that loud speech is considerably lacking in low-frequency components, as compared to a voice of normal intensity.

Let us now consider the effects described by B. F. Miller. According to his paper, voice signals, after having traversed the compressor, show a preponderance of high-frequency components. This effect is explained as follows: Fig. 2C shows the average relation between rms speech pressure per cycle and speech component frequency. Miller obtained the data for this curve from a paper by Dunn and White.[4] It is observed that the presssures corresponding to the lower-frequency (vowel) sounds of speech are very much greater than

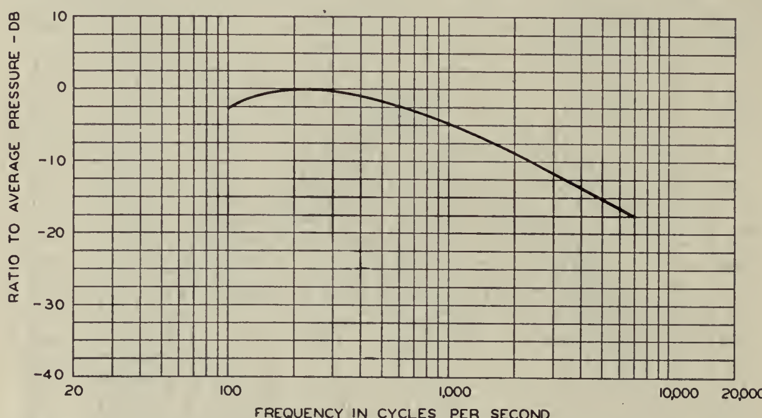

FIG. 2C. Average relation between rms speech-pressure per cycle and speech component frequency.

those corresponding to the higher-frequency (sibilant) sounds. Now, if the amplification of the compressor is inversely proportional to the instantaneous signal voltage, the amplification of the sibilants will be higher than that of the vowels, since the instantaneous voltage corresponding to the sibilants is less than the instantaneous voltage corresponding to the vowels. To correct this condition, Miller recommended an equalizer, inserted between the compressor output terminals and the control rectifier, the frequency response of which was designed to vary according to the inverse of the pressure-frequency distribution of Fig. 2C.

Miller's fundamental and highly commendable paper deserves detailed examination and review. In the first place, it assumes that the frequency characteristic of the speech signal entering the com-

pressor has approximately the characteristics of Fig. 2C. However, in the recording of sound various equalizers are usually inserted in the circuit ahead of the compressor. Some of the factors on which the design of these equalizers are based tend to support this curve, but some do not. Factors which support this curve are the corrections applied for the frequency response of the microphone, the reverberation characteristic of the sound stage, and the changed voice characteristic of the actor speaking in quiet surroundings (effort equalization). The factors which produce a change in the curve of Fig. 2C are the compensations employed to correct for film

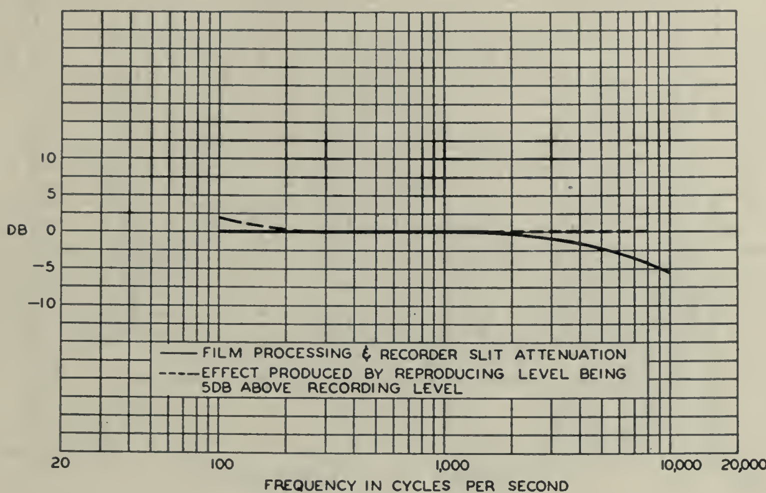

FIG. 2D.

losses, for the recorder slit attenuation, and for the increase in low frequencies occasioned by the reproducing level being (on the average) 5 db above normal speech level. These three factors are represented graphically on Fig. 2D. When they are taken into consideration, the electrical signal characteristic of the human voice at normal level just before entering the compressor assumes the solid curve of Fig. 2E. Therefore, this curve, and not Fig. 2C, should be used in the design of the compressor equalizer.

In the second place, the curve of Fig. 2C will not be the same for extremely low or extremely loud speech and, therefore, if best results are to be expected, it cannot be used indiscriminately for the determination of the compressor equalization characteristic.

In the third place, the question arises as to whether there are significant differences between male and female voices, and also between individual male and individual female voices, which would justify the use of the inverse of the curve of Fig. 2E for the frequency characteristic of the compressor equalizer for normal speech levels.

It is the purpose in the following paragraphs to consider these factors in some detail.

Fig. 2F shows the extreme voice characteristics of men, and Fig. 2G the extreme voice characteristics of women. The data for these

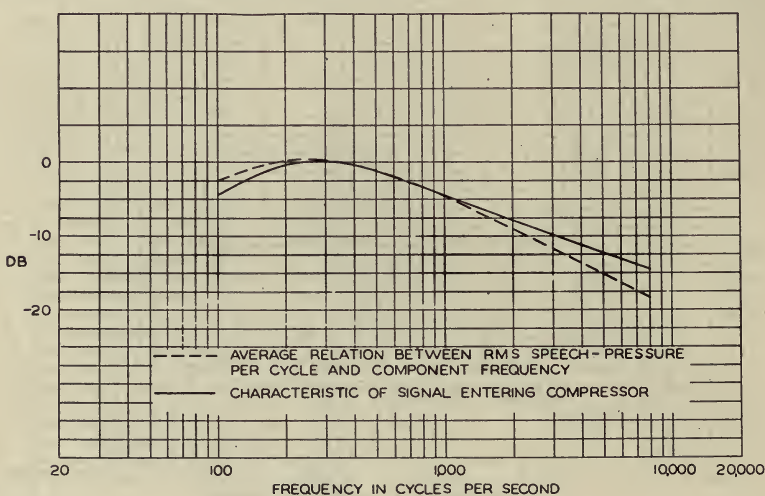

FIG. 2E.

curves were obtained from the aforementioned paper.[4] Fig. 2H shows the envelope of the extreme voice characteristics of both men and women. This limit curve was obtained by plotting the extreme voice characteristics for both men and women, and then tracing the envelope along the curves. The limits are most pronounced between 4000 and 5000 cycles, the difference amounting to 15 db.

None of the above objections, however, should make Miller's *intrinsic* argument invalid; namely, that, for faithful recording, irrespective of the (speech) characteristic of the signal entering the compressor (not the microphone), the inverse of this characteristic should be employed for the frequency response characteristic of the compressor equalizer. If the speech to be recorded is extremely low

or loud, or if its characteristic departs noticeably from the normal characteristic of the speech (individual voice differences), the characteristic of the compressor equalizer should then vary accordingly. Extremely low and extremely loud speech has a characteristic the inverse of which differs from the normal frequency response characteristic of the compressor equalizer to such an extent that this equalizer cannot completely correct for "selective distortion" at all times. Fig. 2J indicates the changes in this equalizer characteristic necessary to accommodate the extremes in voice levels, by showing

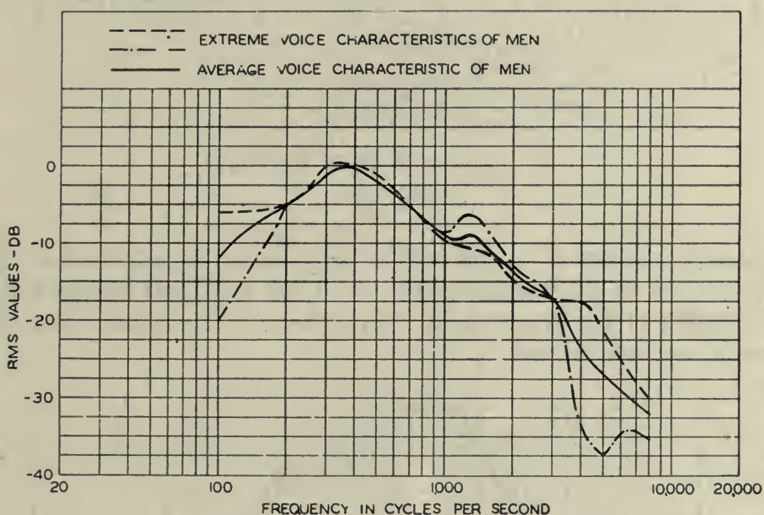

FIG. 2F.

the average voice characteristic of soft, normal, and loud speech "matched" at 1000 cycles.

For best results a variable equalizer should be used in the compressor to accommodate all possible conditions: A compromise curve such as that in Fig. 2E must be employed in the compressor. It will, at least, cover a large number of cases, and will do much to eliminate the hiss of many voices recorded on a recording channel that contains a compressor.

It is sometimes claimed that, since the compressor is an energy-actuated device, no "selective distortion" would occur if the timing in the compressor were kept short enough. Within practical limits, acceptable results can be obtained in this manner. However, the

argument does not appear to be completely true; for, even if no condenser had to be charged in the compressor, and the compressor could be made to react instantaneously with the voltage changes,

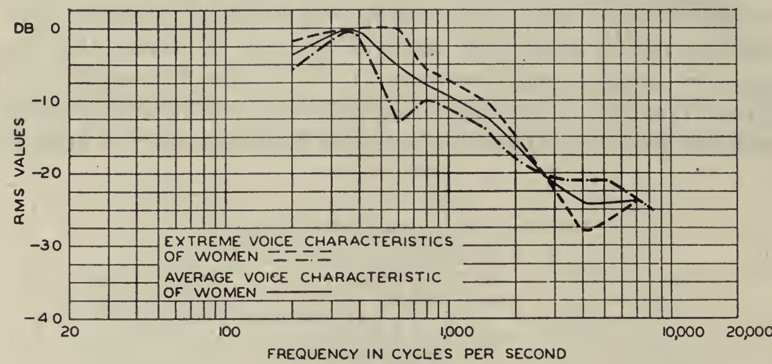

FIG. 2G.

"selective distortion" might still occur because the signal voltage of the sibilant at the beginning of a word can very well be below the "threshold of the compressor" (the volume level below which the compressor will not act).

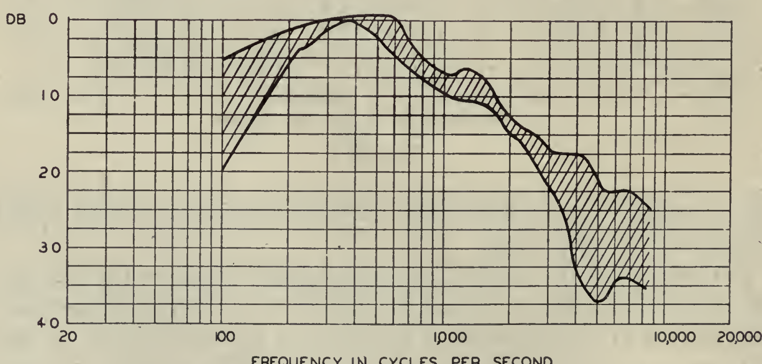

FIG. 2H. Envelope of extreme voice characteristics of men and women.

The colloquialisms, "de-esser" or "de-icer," are sometimes applied to this compressor equalizer.

The conclusions reached as a result of the foregoing observations are:

(*1*) An equalizer of the type described by B. F. Miller, to be inserted between compressor output terminals and the control rectifier for controlling "selective distortion," appears to have merit in recording sound on film.

(*2*) While the frequency characteristic of the equalizer should essentially conform to the inverse of the speech characteristics (Fig. 2C), in practice the amount of equalization in the channel ahead of the compressor, must be taken into consideration in designing the equalizer.

(*3*) The consideration of the region in the speech characteristic below 1000 cycles appears important for very loud speech. It may therefore be advisable to employ two insertion-loss characteristics in the compressor equalizer—one of normal and one for declamatory speech.

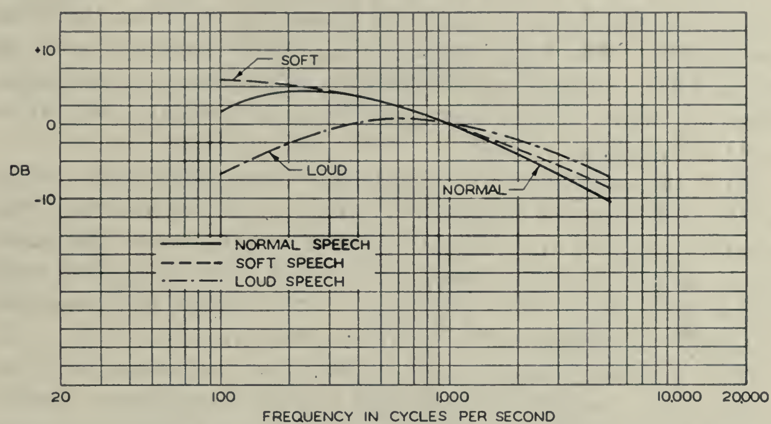

FIG. 2J. Average relation between rms speech-pressure per cycle and speech component frequency; curves matched at 1000 cycles.

PART 3

Recommended Recording Channel Equalization.—In the early days of sound recording, the placement of equalization in various parts of the channel, mainly in the preamplifier and in the mixing console, was determined chiefly by considerations of convenience and immediate economy. For instance, by locating all the required high-frequency compensation in the preamplifier (a method which could be carried out with the aid of only a carbon resistor and a small condenser), there was provided not only a relatively inexpensive means of equalization, but also one which was readily accessible and could be changed quickly. However, as this method became an established practice and the technique of sound recording increased in complexity, the early economic advantages assumed a less obvious character. For instance, when it was decided to change from a nondirectional

to a directional microphone, as during the recording of dialogue within a small "boomy" set, it became necessary (in the absence of a handy soldering iron) to interchange also the preamplifier. Many sound trucks, therefore, carried two, and some trucks even three preamplifiers to accommodate the various microphones.

Soon other complications arose. The recording of a comparatively high-level signal, such as that obtained from a telephone line, called for a separate high-frequency equalizer. The signal could not conveniently be applied to the input of the preamplifier because of hum and general noise trouble resulting when the telephone signal was sufficiently attenuated to meet the input-level requirements of the preamplifier. The signal, therefore, had to be introduced after the preamplifier. Because such occasions were not numerous, the sound recording departments looked upon them as necessary evils which could not easily be avoided.

With the introduction of high-fidelity monitoring and wax or acetate disk recording equipments, further complications arose. Satisfactory operation of these units could be obtained only if the equalization for film processing losses, recorder slit attenuations, and other factors was omitted from the signal. This meant, of course, that suitable "decompensators" had to be employed.

If an abnormal amount of high-frequency compensation is required, it is often difficult to provide it in the preamplifier. For instance, if a velocity microphone is desired for dialogue recording, which may call for an equalization in excess of 10 db at 6000 cycles, it is not easy to locate all this compensation in the preamplifier. The difficulty lies not so much in increasing the high-frequency response of the amplifier by 10 db at 6000 cycles, but in securing the most desirable response characteristic between 1000 and 6000 cycles by any simple, compact means of equalization.

Other disadvantages could be enumerated in connection with the described method of placing the high-frequency equalization in the preamplifier. These, no doubt, would vary with the modes and processes of the different studios, and hence might be more serious in one studio than in another. However, it is generally agreed that the assignment of the high-frequency compensation to the preamplifier is no longer the economic nor the convenient solution it once was.

Location of the entire low-frequency (so-called "dialogue") equalization in the mixing console is likewise an established outgrowth of an early procedure of expediency. It was at one time considered

satisfactory to allow the mixer on the set to control the general character, and to some extent also, the intelligibility, of the voices to be recorded. With the advent of the compressor, however, some of the functions of the mixer along this line became curtailed. Moreover, by locating all dialogue equalization in the mixing console, which is always ahead of the usual compressor in the circuit, a certain accentuation of the low frequencies occurs with increasing voice level. This accentuation is caused by the compressor action, which tends to "flatten out" the signal characteristic by acting only on those signal components which are above its threshold. If the low-frequency components are severely attenuated ahead of the compressor, so that they lie below the compressor threshold and hence must pass through the instrument uncompressed, the resulting output from the compressor will show an increased amount of low-frequency response. This change in voice quality is particularly noticeable when an actor delivers a declamatory speech. Acoustical studies have proved that declamatory speech contains fewer low-frequency components than normal speech, just as intimate speech contains a preponderance of low notes. Compressor action, however, tends to "wipe out" or to eliminate this lack of lower registers during declamation, making the voice sound less high-pitched. Whether this characteristic is beneficial is at present a moot question. It has been said by some that it results in greater carrying power of declamatory speech.

Having stated the problem of high-fidelity recording on film, we will now discuss steps that may be taken in the direction of a satisfactory solution.

Low-Frequency Equalization.—A consideration of the various conditions which occur in the normal course of dialogue recording favors the "splitting" of the low-frequency equalization and distributing it both before and after the compressor. It appears logical that a mixer should be able to control to some extent the intelligibility of the recorded sound, as by attenuating some low-frequency components in an unusually heavy voice or in speech uttered in a small, boomy set. For this purpose the mixer should have at his control in the mixing console a small amount of variable low-frequency compensation, for example, 6 db at 100 cycles. If microphones are changed during a production, a change in the required equalization can just as easily be effected by a variable equalizer inserted after the compressor as by locating all the compensation in the console. In the case of a sound truck, all that the mixer has to do is

to telephone to the recordist in the truck to adjust the dialogue equalizer in the rack to the required amount, a procedure which can also be employed very easily in the case of a centralized recording system. If this system (of "splitting" the low-frequency equalization) is adopted, the following benefits will result:

(*1*) The low-frequency components will not be emphasized so much by the compressor. To make this point quite clear, consider Fig. 3A, which represents a somewhat simplified schematic of the prevalent conditions, and consists of a top and a bottom figure. Curve *A* of the top figure shows the present type of dialogue equalization, which attenuates 100 cycles by approximately 12.5 db. In the normal voice-characteristic the 100-cycle component is about 2.5 db below the

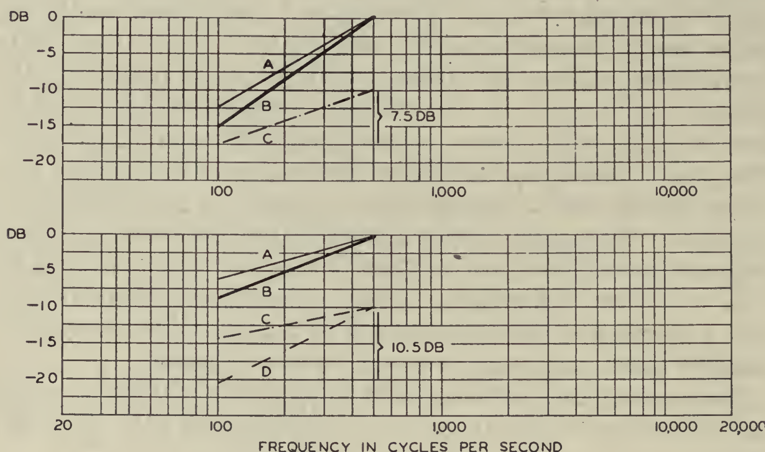

FIG. 3A. Compressor characteristics.

500-cycle component, consequently the signal entering the compressor has more nearly the characteristic indicated by Curve *B*. Curve *C* shows the frequency characteristic of the compressor output signal when the device is set for a compression ratio of 20 into 10 db. As shown on the figure, the 100-cycle component is now only 7.5 db below the 500-cycle component, indicating that the 100-cycle component was accentuated 12.5 − 7.5 = 5 db. In the bottom part of Fig. 3A, Curve *A* represents half of the total dialogue equalization which is introduced ahead of the compressor. Because in the normal voice characteristic the 100-cycle component is about 2.5 db below the 500-cycle component, the signal entering the compressor has more nearly the characteristic indicated by Curve *B*. Curve *C* shows the frequency characteristic of the compressor output signal when the compressor is set for a compression ratio of 20 into 10 db. Since this signal will be subjected to the effect of the second part of the dialogue equalization placed after the compressor, the resulting signal will have more nearly the characteristic of Curve *D*. As shown on the figure,

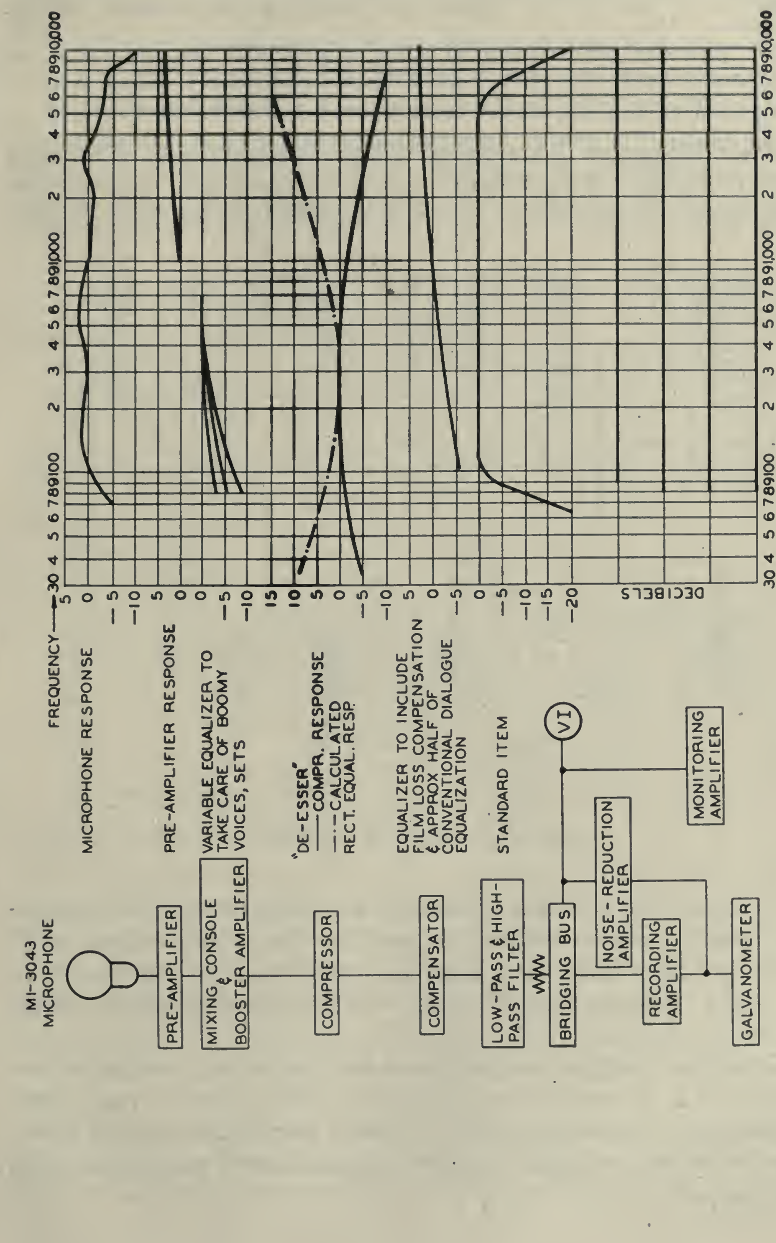

FIG. 3B. Recommended equalizer characteristic and equipment arrangement for RCA recording channel.

the 100-cycle component is now 10.5 db below the 500-cycle component, indicating that the 100-cycle component was accentuated only 12.5 − 10.5 = 2 db, as against 5 db when all of the dialogue equalization was placed ahead of the compressor.

(*2*) Incidental low-frequency set noises, stage rumble, *etc.*, will not be accentuated so much when part of the dialogue equalization is placed ahead of and part after the compressor, for the same reason as described above.

High-Frequency Equalization.—The disadvantages of locating all the high-frequency equalization in the preamplifier have been discussed in some detail. From a consideration of these factors,

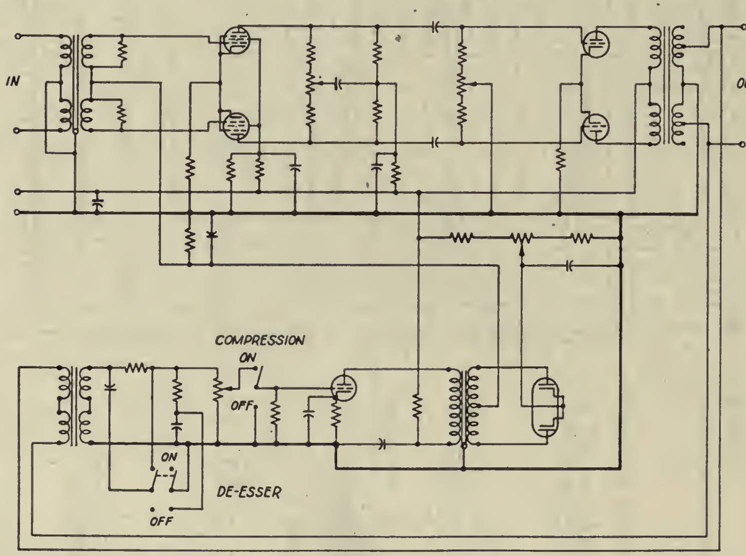

FIG. 4A. Compressor schematic.

it becomes evident that a much more desirable high-frequency equalization system consists in locating the so-called fixed compensation (film losses, recording slit attenuation) after the compressor and to introduce the so-called microphone compensation ahead of the compressor.

Limitation.—When changing from one kind of microphone to another kind in the course of recording, it is still necessary to change the preamplifier. This means that a sound truck may have to carry more than one preamplifier if more than one kind of microphone is to be employed.

Fig. 3B shows the recommended arrangement of equipment items and equalizer characteristics for a film recording channel which fulfills the requirements previously discussed.

PART 4

Experimental Work.—A recording channel was set up in accordance with the block schematic illustrated in Fig. 3B. This block schematic shows the recommended arrangement of equipment items and their frequency characteristic. The combination results in a

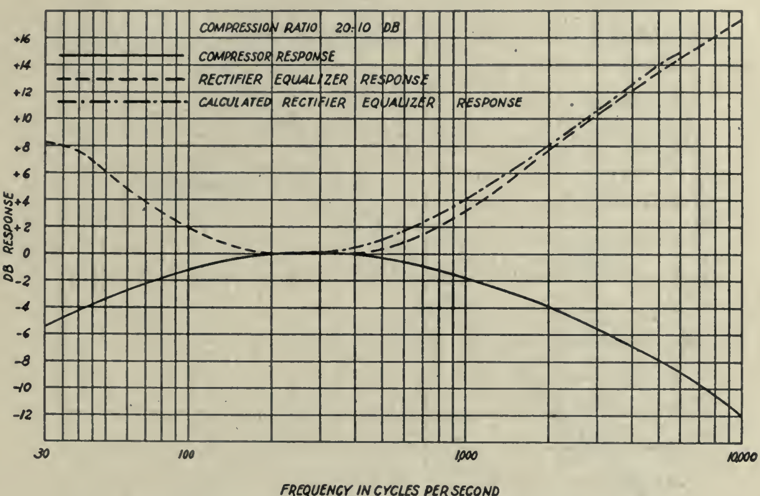

FIG. 4B. Compressor frequency characteristic.

variable-area film recording channel which conforms to the theoretical requirements derived in the preceding parts of this paper. All tests were made in the RCA Hollywood Film Recording Studio, as the equipment available there provided great flexibility of frequency characteristic, level relationships between various amplifiers, change of compression ratio, and other equally valuable considerations. Instead of the mixer, which is normally employed in studio channels, the rerecording console with its array of equalizers was used.

It should be understood that the tests to be described later were made for the purpose of proving or disproving the validity of the theoretical conclusions arrived at in the preceding text, without re-

gard for the practical limitations which might be encountered in the studios because of presently available equipment or operational technique. Live talent, male and female, was used as a source of sound, and a standard recording channel was used as a basis of comparison.

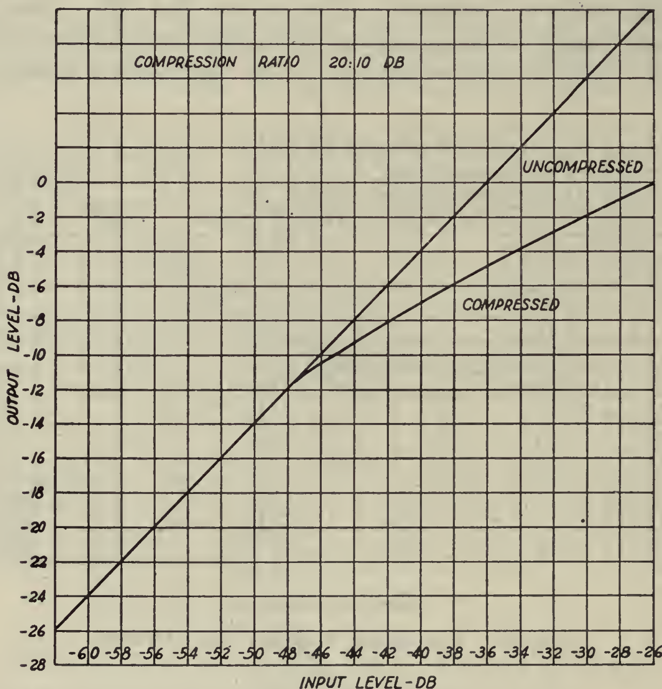

FIG. 4C. Compression characteristic of compressor.

Let us consider each equipment item used in this experimental channel and discuss the differences between it and corresponding items used in recording studios.

A unidirectional microphone connected for an output impedance of 500 ohms was fed to a microphone amplifier of 250 ohm nominal input impedance. This microphone amplifier had been modified for a frequency response as shown on Fig. 3B. Feeding the 500-ohm microphone output into a nominal 250-ohm input results in 3 db more output from the microphone with a negligible loss of high-frequency response, and a 3-db improvement of signal-to-noise ratio.

A variable rerecording compensator was set to duplicate the variable equalizer characteristic shown on Fig. 3B to take care of boomy sets, heavy voices, *etc.*

A compressor was modified to contain the circuit shown on Fig. 4A. This was done in order to duplicate the compressor frequency characteristic illustrated on Fig. 4B to eliminate the "relative spectral energy distortion."

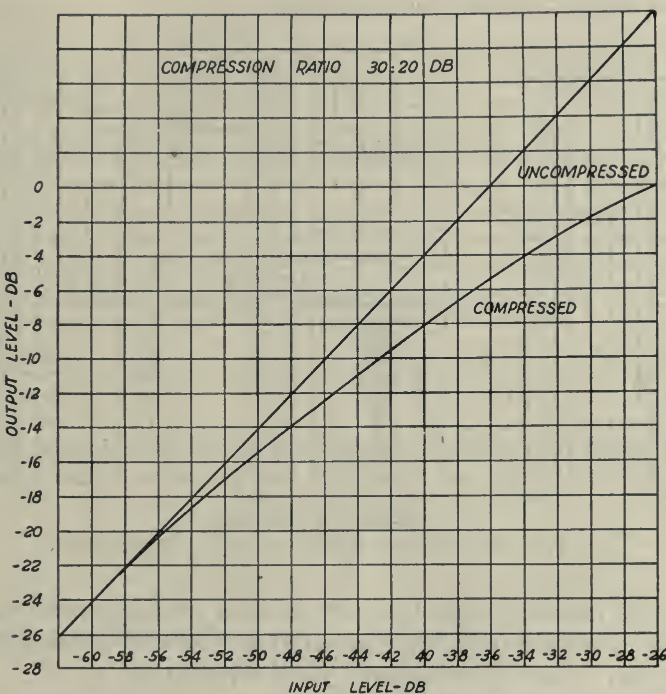

FIG. 4D. Compression characteristic of compressor.

Compression characteristics for compression ratios of 20 into 10 db and 30 into 20 db are shown on Fig. 4C and 4D.

A film loss and dialogue equalizer, whose schematic and frequency characteristic are in accordance with the schematic shown on Fig. 4E, was used.

A 6000-cycle low-pass filter was employed, together with an 80-cycle high-pass filter. Both filters are standard equipment items and were not changed.

In order not to conceal compressor action by the effects of noise reduction (clipping of the beginning of sounds because of the normal noise-reduction circuit timing), it was decided to make all tests without noise reduction.

An RCA type *MI-3233B* bridging amplifier was employed to drive the recording galvanometer.

The regular rerecording monitoring system, consisting of a suitable monitoring decompensator, 50-w power amplifier, and a two-way speaker system, was used for monitoring.

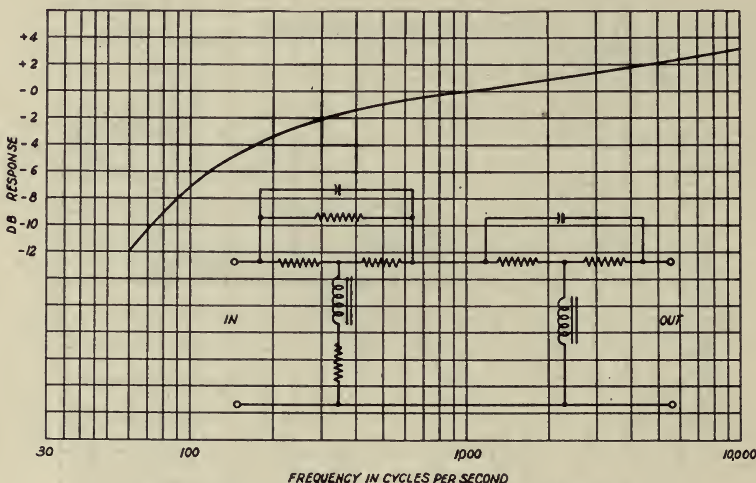

FIG. 4E. Film loss and dialogue equalizer characteristic.

Results obtained from this experimental channel were compared against a standard recording channel whose block schematic is shown in Fig. 4F. The block schematic is self-explanatory.

A series of tests was made during which a male and a female voice (live talent) repeated the same dialogue under varying conditions. These variations in conditions cover changes of compressor acting time from 0.7 to 10 milliseconds and compressor release time from 0.1 sec to 0.5 sec, change of compression ratio between 20 into 10 db and 30 into 20 db, and use or omission of the de-esser. These tests were divided into two groups, namely, listening tests and recording tests. Listening tests were made for all conditions. During these tests the performance of the experimental channel was compared against the standard channel. An instantaneous comparison

was possible by means of a suitable switching arrangement. During the listening tests the fact was definitely established that an unmistakable improvement in quality was obtained when the de-esser circuit was used in the compressor. Consequently, no recording tests without de-esser have been made. Actual recordings under all conditions with de-esser and through the standard channel as shown on Fig. 4F were made. Particular attention was paid during these tests to maintaining equal modulation level on the film for all varying conditions.

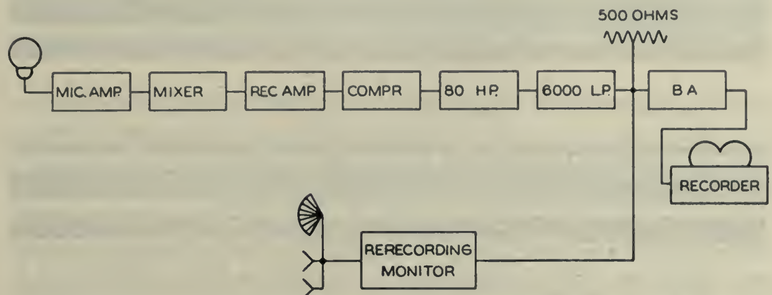

FIG. 4F. Standard recording channel.

Prints of these recording tests were run through the RCA rerecording channel before a group of listeners, who voted for what they thought sounded best. These listening tests were spaced over several days in order to avoid fatigue of the observers. Six of the original eleven tests were finally eliminated. Further listening tests brought the unanimous opinion that test two sounded best. The conditions under which these test recordings were made were as follows:

Compression ratio	20 into 10
Compressor acting time	0.0007 sec
Compressor release time	0.5 sec
De-esser	in circuit.

In order to illustrate compressor acting time, Figs. 5 and 6 are shown here. Fig. 5 shows compressor action when the level of a 5000-cycle tone is suddenly increased by 20 db. The compressor used in the standard recording channel had an acting time of about 0.002 sec and a release time of about 0.5 sec which corresponds to the timing trace shown on the top.

An acting time of 0.0007 sec and a release time of about 0.5 sec gave the best results in the compressor in the experimental channel. The second trace from the top corresponds to this timing. The bottom trace shown on Fig. 5 corresponds to an acting time of 0.0002 sec and a release time of 0.5 sec.

Recording tests under these conditions were not included in this investigation, as earlier experiments covering the use of such ultra-

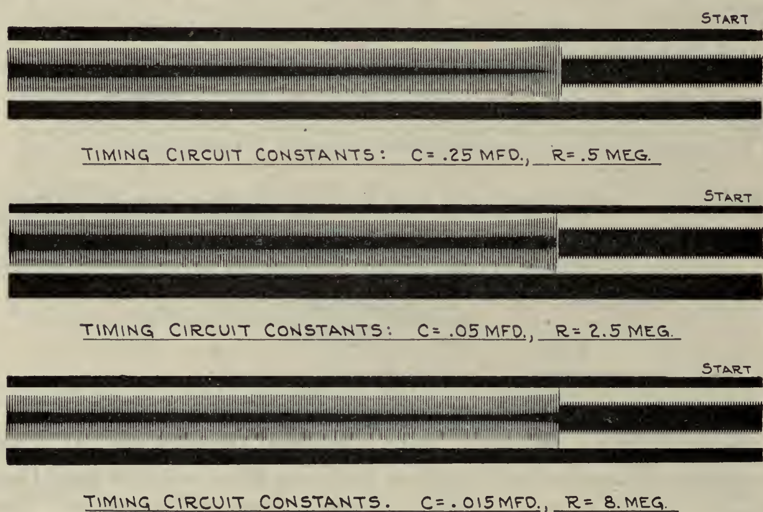

FIG. 5. Operating time characteristics of *MI-10206* electronic mixer; compression ratio 20 db into 10 db (f = 5000 cycles).

fast compressor timing have shown that it is impractical for production conditions. In order to utilize such fast acting time, it would be necessary to maintain very accurate tube balance in the compressor which, owing to limitation of tube and power supply stability and the pressure under which motion pictures are made, is not possible.

Fig. 6 shows the appearance of a speech recording made with the different timing circuit constants shown on Fig. 5. The overshooting with the slow acting time of 2 milliseconds is quite evident.

PART 5

Conclusions.—From the results of the foregoing tests, the following conclusions have been formed:

(*1*) When comparing the experimental channel, set up in conformity with the block diagram on Fig. 3B with the standard channel, an improvement in sound quality is obtained, even when the compressor in the experimental channel is operated without de-esser, having an acting time of 2 millisec and release time of 0.5 sec. This improvement results from placing part of the dialogue equalization as well as part of the high frequency equalization after the compressor, which arrangement reduces the "wiping out" action of equalization by the compressor. This observation was made when comparing conditions 1C and 1D against the standard channel.

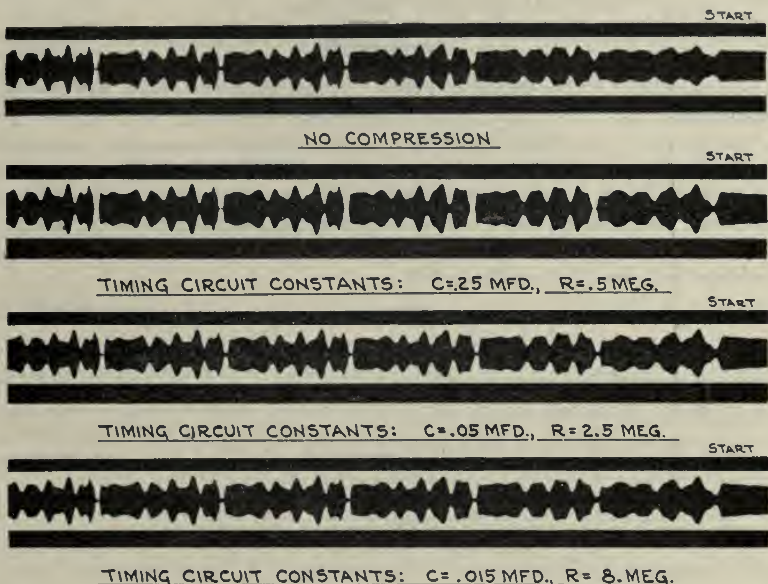

FIG. 6. Operating time characteristics of *MI-10206* electronic mixer; compression ratio 20 db into 10 db (speech).

(*2*) Adding the de-esser circuit to the compressor in the experimental channel eliminates to a large extent the hisses and accentuated sibilants which can be noticed without it.

(*3*) Speeding up the acting time of the compressor in the experimental channel to 0.0007 sec reduces sibilant accentuation still further. The sound quality thus obtained is smooth and natural and compares to what a listener would hear on a recording stage if he were located in the position of the microphone.

(*4*) It has definitely been established that the addition of the de-esser circuit and speeding up in acting time *together* result in the best recording quality.

(*5*) When the compressor acting time is speeded up to 0.0007 sec, the compressor release time should be slowed down to 0.5 sec to maintain adequate filtering of the gain change control voltages. If adequate filtering is not maintained, reproduction becomes rough.

(6) A close qualitative agreement between theoretical analysis and practical test results has been established. Quantitatively, the tests differed from the theoretical optimum only in this respect that because of practical limitations it was not possible to obtain exactly the calculated sibilant de-accentuation in the compressor. (See Fig. 4B.) This deviation, however, was rather small, and cannot influence the qualitative trend.

(7) An analysis has been presented which is applicable to all types of recording channels, which may use any of the available recording media as, for instance, variable-area or variable-density on film, lateral or vertical cut on acetate or wax, steel-tape recording, or any other recording media.

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WIDE-RANGE LOUDSPEAKER DEVELOPMENTS*

H. F. OLSON** AND J. PRESTON**

Summary.—*Two unit direct-radiator loudspeakers may be constructed in many different ways. In order to determine some of the characteristics, a number of experimental designs were built and tested. As a result of these experiments, it appeared that the duo-cone loudspeaker, consisting of two coaxial, congruent, separately driven cones, possessed many constructional, theoretical, and experimental advantages. Consequently, a detailed theoretical and experimental investigation of the duo-cone loud-speaker was carried out to determine the optimum values for the constants of the system from the standpoint of the following characteristics: pressure response, directional pattern, distortion, and transient response. The results of these investigations are included.*

Introduction.—The almost universal use of the direct-radiator loudspeaker is a result of its simplicity of construction, small space requirements and the relatively uniform response frequency characteristic. Uniform response over a moderate frequency band may be obtained with any simple direct-radiator loudspeaker. However, reproduction over a wide frequency range is restricted by practical limitations. The portion of the speech range required for intelligibility falls in the midaudio band. The range of the fundamental frequencies of most horn, reed, and string instruments also falls within this band. This is rather fortunate because it is a very simple task to build mechanical and acoustical vibrating systems to cover only this midfrequency band. The two extreme ends of the audio-frequency band are the most difficult to reproduce with efficiency comparable to the midfrequency range. Inefficiency at the low frequencies is primarily caused by a small radiation resistance. Inefficiency at the high frequencies is primarily caused by large mass reactance.

The volume range is another factor involved in sound reproduction. In the middle frequency band the ear has a volume range of a million to one in pressure, or a trillion to one in energy. To build

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** Research Department, RCA Laboratories Division, Princeton, N. J.

linear reproducing apparatus for this tremendous range is practically impossible today. As a matter of fact, it is not practical to reproduce the volume range of all musical instruments.

An increase in the volume and frequency ranges of the loudspeaker multiplies the problems connected with obtaining the proper directional pattern, low nonlinear distortion and suitable transient response. The directional characteristics of the conventional direct-

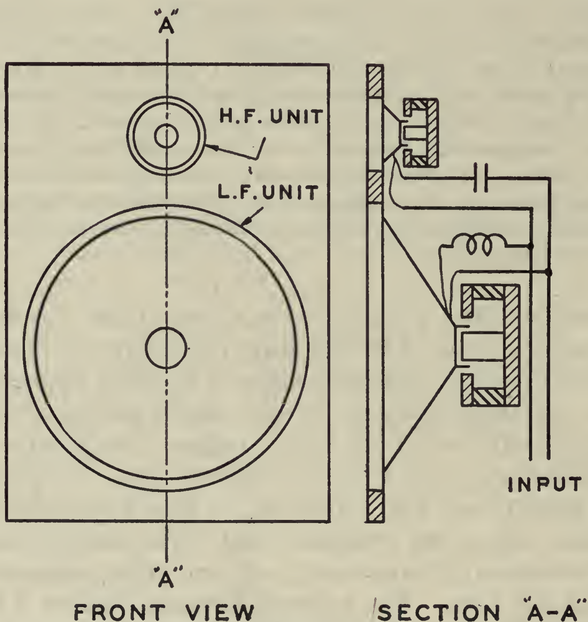

FIG. 1. A coplaner combination of low- and high-frequency direct-radiator loudspeaker units.

radiator loudspeaker are quite adequate for the frequency range of the present-day broadcast receivers. However, when the high-frequency range is increased by one to two octaves, the directional pattern becomes quite narrow and some consideration must be given to this problem. The problem of nonlinear distortion is multiplied several times by the addition of one or two octaves. The additional volume range, of course, complicates the problem of nonlinear distortion. It has been found that poor transient response is not objectionable in the case of a loudspeaker with a limited frequency range—in some cases it actually enhances the reproduction. However, a wide-range high-

fidelity loudspeaker should exhibit good transient response. From the above discussion it will be seen that additional volume and frequency ranges increase the complexity of the technical problems in loudspeaker design and manufacture.

Wide frequency range, low distortion loudspeakers are required for monitoring in radio and television broadcasting, phonograph, and sound motion picture recording and high quality sound systems. The direct-radiator loudspeaker is particularly suited for these applications because the acoustic power required is relatively low and the space requirements rather limited.

It is the purpose of this paper to describe the following: the development work on a wide-range direct-radiator loudspeaker; the performance of an experimental duo-cone direct-radiator loudspeaker.

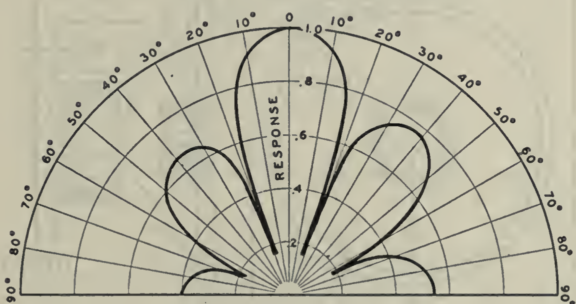

FIG. 2. The directional characteristics in the overlap region of the coplaner combination of low- and high-frequency direct-radiator loudspeaker units shown in Fig. 1.

Two-Unit Loudspeakers.—Two-unit loudspeakers may be constructed in many different ways. In order to determine some of the characteristics, a number of experimental designs were built and tested. Some of the theoretical and practical advantages and disadvantages will be described.

The simplest two-unit, direct-radiator loudspeaker consists of a small cone unit and a large cone mounted on the front face of a flat baffle as shown in Fig. 1. If the response covers the frequency range from 40 to 15,000 cycles the natural overlap region will be somewhere between 1000 and 2000 cycles. A system of the type depicted in Fig. 1 consists of a cone 15 in. in diameter in the low-frequency unit and 2 in. in diameter in the high-frequency unit. Owing to the mounting arrangements of the two units the spacing between the two units

in the baffle was 15 in. The middle of the overlap region was placed at 1500 cycles. The directional pattern at 1500 cycles is shown in Fig. 2. Complete destructive interference occurs when the distance between the two units is one-half wavelength and odd multiples of one-half wavelength. The type of directional characteristic shown in Fig. 2 introduces frequency discrimination for points removed from the axis in a very important frequency band.

In the next experiment, the high-frequency loudspeaker unit was placed coaxially inside the low-frequency unit as shown in Fig. 3.

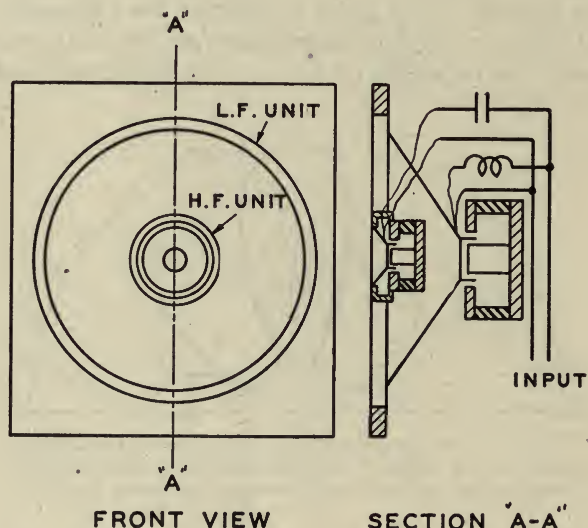

FIG. 3. A coaxial combination low- and high-frequency direct-radiator loudspeaker units.

This construction improved the directional pattern in the overlap region. However, the sound which was diffracted around the high-frequency unit and reflected from the low-frequency cone interfered with the direct radiation. The result of this process is a nonuniform response frequency characteristic as shown in Fig. 4.

In the next experiment a small cellular horn loudspeaker was used as the high-frequency loudspeaker. The horn loudspeaker was placed in a baffle above the low-frequency unit as shown in Fig. 5. This system exhibited the same type of directional pattern in the overlap frequency region as the system of Fig. 1.

Following the above experiment the cellular horn loudspeaker was arranged coaxially with respect to the low-frequency loudspeaker as shown in Fig. 6. This system exhibited diffraction characteristics similar to those of Fig. 3. There was an additional factor; namely, the source of the high-frequency sound was several inches behind the source of the low frequency sound. This path amounts to almost a wavelength in the overlap frequency region. This is an undesirable feature, particularly, in the case of the reproduction of transient sounds.

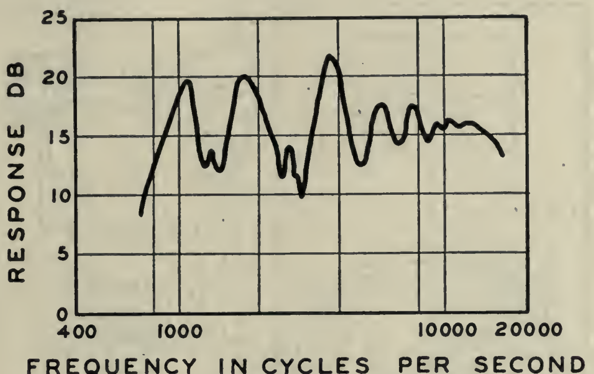

FIG. 4. The response frequency characteristic of the high-frequency unit of the coaxial combination of low- and high-frequency direct-radiator loudspeaker units shown in Fig. 3.

From the above experiments it appeared undesirable to place the high-frequency unit in front of the low-frequency unit. This feature can be obviated by making the pole for the low-frequency unit a portion of the high-frequency horn as shown in Fig. 7. The response frequency characteristic obtained on this system was smooth. In addition, the directional pattern was acceptable particularly when a wide angle low-frequency cone was used. The difference in path length between the source of the low- and high-frequency units was still an undesirable feature.

There is another problem when a horn and direct-radiator loudspeaker are combined; namely, the difference in efficiency. The efficiency of a horn loudspeaker is from 10 to 20 db greater than the direct-radiator loudspeaker. This means that an attenuation network must be used with the horn unit to obtain comparable efficiencies and uniform response from the combination of the two units.

In the next experiment two cone loudspeaker units were combined so that the large cone was a continuation of the small cone as shown in Fig. 8. This system has been termed a duo-cone loudspeaker. The combination system shown in Fig. 8 eliminates the path difference factor because in the overlap region the two cones vibrate together as a single cone.

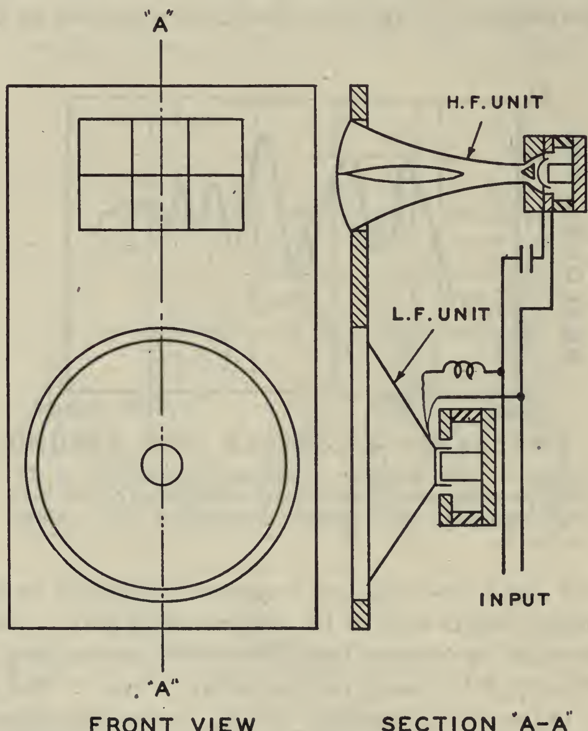

FIG. 5. A coplaner combination of a direct-radiator low-frequency loudspeaker unit with a cellular horn high-frequency loudspeaker unit.

As a result of the above experiments it appeared that the duo-cone loudspeaker possessed many constructional, theoretical, and experimental advantages. In view of this, it was decided to make a detailed investigation of the duo-cone loudspeaker. It is the purpose of the sections which follow to describe in detail some of the characteristics of the duo-cone loudspeaker.

Theoretical Considerations.—The performance of a direct-radiator loudspeaker may be obtained from theoretical considerations.[1] Theoretical investigations are useful in determining the dimensions of the units, the masses of the voice coils and cones, the air gap flux, the fundamental resonant frequencies, and other relevant factors. Proper evaluation of these factors is important in obtaining a scientifically co-ordinated loudspeaker system. It is the purpose of this section to outline theoretically the action of the duo-cone loudspeaker consisting of two congruent, coaxial direct-radiator loudspeaker systems.

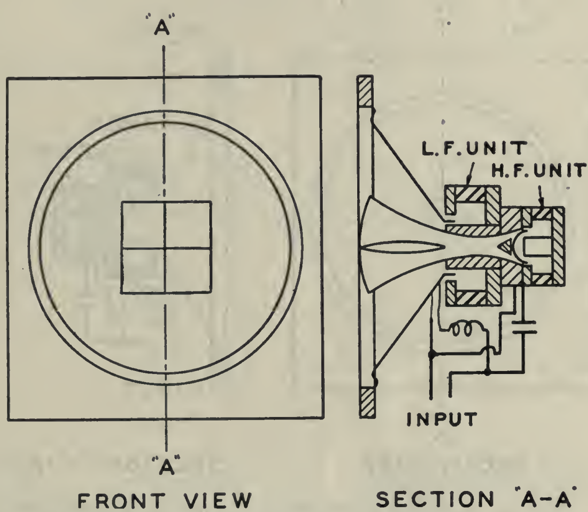

FIG. 6. A coaxial combination of a direct-radiator low-frequency loudspeaker unit with a cellular horn high-frequency loudspeaker.

A cross-sectional view, voice coil circuit, and the mechanical circuit of the low frequency unit of the duo-cone loudspeaker are shown in Fig. 9. The total mechanical impedance of the vibrating system at the voice coil is

$$z_{MT} = r_{MS} + r_{MA} + j\omega m_C + j\omega m_A - \frac{j}{\omega C_{MS}} \tag{1}$$

where r_{MS} = mechanical resistance of the suspension system, in mechanical ohms,

r_{MA} = mechanical resistance of the air load, in mechanical ohms,

m_C = mass of the cone and the voice coil, in grams,

m_A = mass of the air load, in grams, and
C_{MS} = compliance of the suspension system, in centimeters per dyne.

Eq (*1*) may be written as follows:

$$z_{MT} = r_{MS} + r_{MA} + jx_{MC} + jx_{MA} - jx_{MS} \tag{2}$$

where r_{MS} = mechanical resistance of the suspension system, in mechanical ohms,
r_{MA} = mechanical resistance of the air load, in mechanical ohms,
x_{MC} = ωm_C = mechanical reactance of the voice coil and cone,

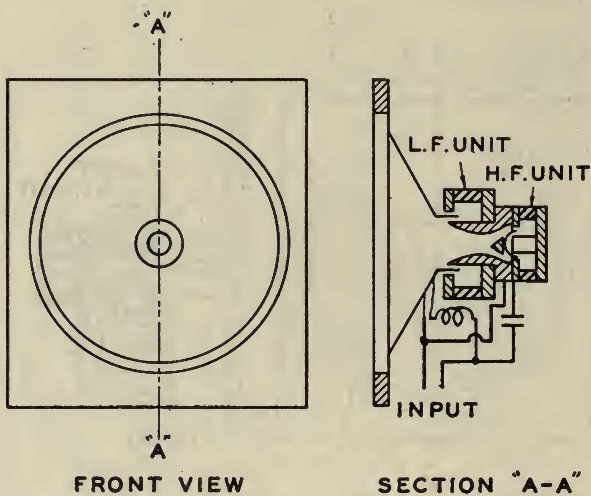

FIG. 7. A coaxial combination of a direct-radiator low-frequency loudspeaker unit with a horn high-frequency loudspeaker unit.

x_{MA} = ωm_A = mechanical reactance of the air load, in mechanical ohms, and

x_{MS} = $\dfrac{1}{\omega C_{MS}}$ = mechanical reactance of the suspension system, in mechanical ohms.

The mechanical resistance and mechanical reactance of the air load may be obtained from Fig. 10.

The motional impedance,[2] in abohms, of the mechanical system is

$$z_{EM} = \frac{(Bl)^2}{z_{MT}} \tag{3}$$

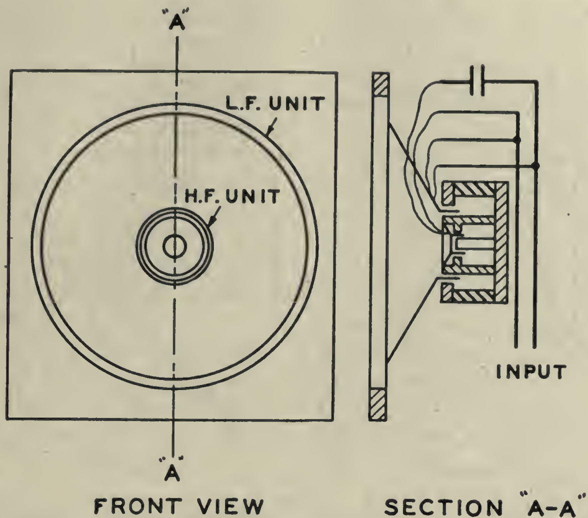

FIG. 8. A congruent coaxial combination of low-frequency and high-frequency direct-radiator loudspeaker units.

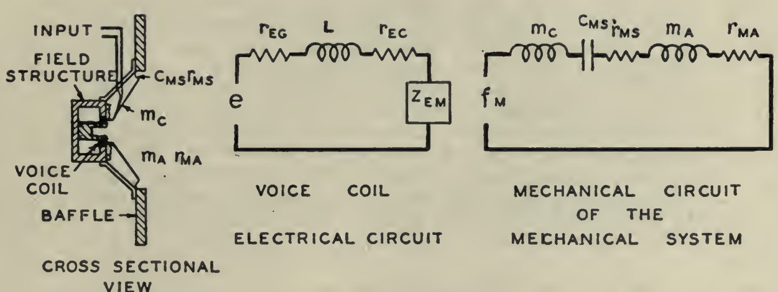

FIG. 9. Cross-sectional view, electrical circuit, and mechanical circuit of the low-frequency portion of a duo-cone loudspeaker. In the electrical circuit: r_{EG}, the internal electrical resistance of the generator; r_{EC} and L, the electrical resistance and inductance of the voice coil; Z_{EM}, the electrical motional impedance, e, the voltage of the electrical generator. In the mechanical circuit: m_C, the mass of the cone and voice coil; C_{MS}, the compliance of the suspension system; r_{MS}, the mechanical resistance of the suspension system; m_A and r_{MA}, the mass and mechanical resistance of the air load; f_M, the mechanomotive force in the voice coil.

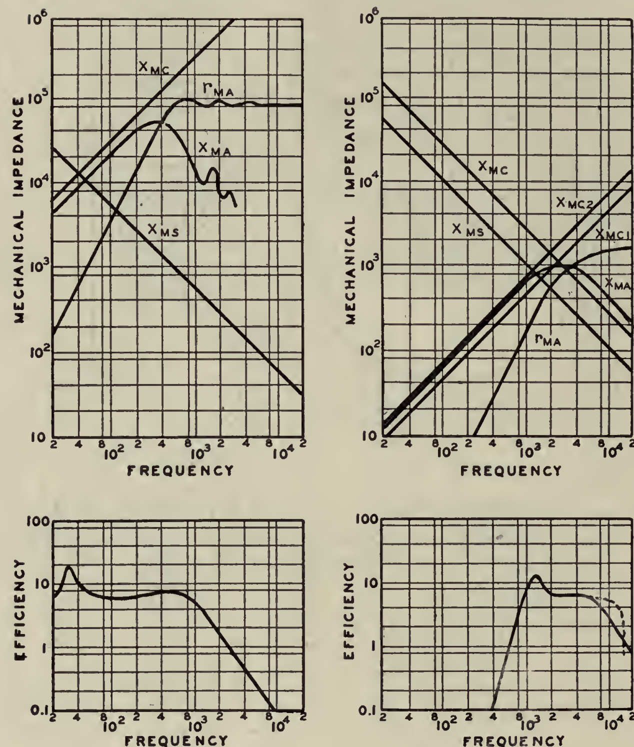

FIG. 10. Mechanical impedance and efficiency frequency characteristics of the low- and high-frequency units of the duocone loudspeaker. In the low-frequency unit: x_{MC}, the mechanical reactance of the cone and coil; x_{MA} and r_{MA}, the mechanical reactance and mechanical resistance of the air load; x_{MS}, the mechanical reactance of the suspension system. In the high-frequency unit: x_{MC1} and x_{MC2}, the mechanical reactances of the voice coil and cone: x_{MA} and r_{MA}, the mechanical reactance and mechanical resistance of the air load; x_{MS}, the mechanical reactance of the suspension system: x_{MC}, the mechanical reactance of the air cavity behind the cone.

where B = flux density in air gap, in gausses,
l = length of the conductor in the voice coil, in centimeters, and
z_{MT} = mechanical impedance of the mechanical system, in mechanical ohms.

The efficiency of the loudspeaker is the ratio of the sound power output to the electrical input. The efficiency may be obtained from the voice coil circuit of Fig. 9 and expressed as follows:

$$\mu = \frac{r_{ER}}{r_{EC} + r_{EM}} \times 100\% \tag{4}$$

where r_{ER} = component of the motional resistance caused by the radiation of sound, in abohms,
r_{EM} = total motional resistance, in abohms, and
r_{EC} = damped resistance of the voice coil, in abohms.

The components r_{ER} and r_{EM} may be obtained from Eqs (*1*), (*2*), and (*3*).

From Eqs (*2*), (*3*), and (*4*) the efficiency, in per cent, of the loudspeaker is

$$\mu = \frac{(Bl)^2 r_{MA}}{(Bl)^2 (r_{MS} + r_{MA}) + r_{ED}[(r_{MC} + r_{MA})^2 + (x_{MA} + x_{MC} - x_{MS})^2]\, 10^9} \times 100 \tag{5}$$

Above the fundamental resonant frequency the mechanical reactance caused by the suspension system is small compared to the mechanical reactance of the cone and coil. Since r_{MA} is small compared to x_{MA} and x_{MC}, Eq (*5*) becomes

$$\mu = \frac{(Bl)^2\, r_{MA}}{r_{EC}\,(x_{MA} + x_{MC})^2\, 10^9} \times 100. \tag{6}$$

In terms of the resistivity and density of the voice coil, Eq (*6*) becomes,

$$\mu = \frac{B^2\, r_{MA} m_1}{\rho K_r\,(x_{MA} + x_{MC})^2} \times 100 \tag{7}$$

where m_1 = mass of the voice coil, in grams,
ρ = density of the voice coil conductor, in grams per cc, and
K_r = resistivity of the voice coil conductor, in ohms per cc.

The relation between the efficiency and the ratio of the mass of the coil to the mass of the cone and air load may be obtained from Eq. (*7*). The maximum efficiency occurs when the mass of the cone is equal to the mass of the coil.

The cone diameter of the low-frequency unit used in the duo-cone loudspeaker is 15 in. The mechanical resistance and reactance characteristics of the elements of the vibrating systems are shown in Fig. 10. For the air load on the large cone it is assumed that it is mounted in an infinite baffle.

The efficiency in which all the elements of the vibrating system are included may be obtained from Eq (*5*). The resistance r_{MC} caused by

suspension system is also a factor in the efficiency in the region of resonance. The mechanical resistance, r_{MS}, of the suspension system of the large cone is 2400 mechanical ohms.

The efficiency characteristic is shown in Fig. 10. It will be noted that the efficiency is higher at the resonant frequency. However, when coupled to a vacuum tube driving system the motional impedance is also increased which produces the power input to the voice coil. For this reason, the response is not accentuated to the degree depicted by the peak in the efficiency characteristic. It will be seen that the efficiency decreases very rapidly below the resonant frequency. Therefore, in a direct-radiator loudspeaker the response limit at the low-frequency end of the frequency range is determined by the resonant frequency of the system.

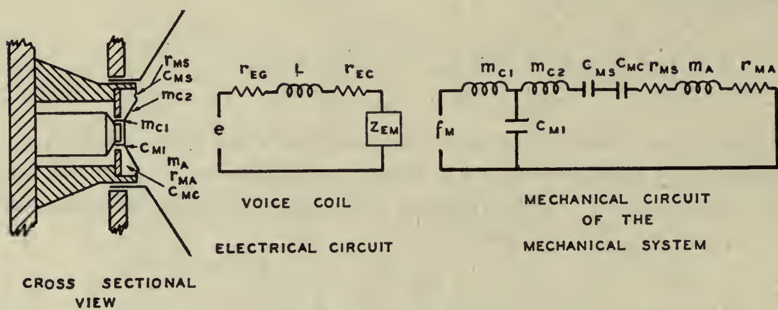

FIG. 11. Cross-sectional view, electrical circuit and mechanical circuit of the high-frequency portion of a duo-cone loudspeaker. In the electrical circuit: r_{EG}, the internal electrical resistance of the generator; r_{EC} and L, the electrical resistance and inductance of the voice coil; z_{EM}, the electrical motional impedance, e, the voltage of the electrical generator. In the mechanical circuit: m_{C1}, the mass of the voice coil; m_{C2}, the mass of the cone; C_{MS}, the compliance of the suspension system; r_{MS}, the mechanical resistance of the suspension system; m_A and r_{MA}, the mass and mechanical resistance of the air load; C_{MC}, the compliance of the air cavity behind the cone; C_{M1}, the compliance between the voice coil and cone; f_M, the mechanomotive force in the voice coil.

The motional impedance of a dynamic loudspeaker is given by Eq (*3*). The normal impedance, in abohms, of voice coil is given by

$$z_{EN} = z_{EM} + z_{ED} \qquad (8)$$

where z_{EM} = motional electrical impedance, in abohms, and
z_{ED} = electrical impedance of the voice coil in the absence of motion, that is blocked, in abohms.

A cross-sectional view, voice coil circuit, and mechanical circuit of the high-frequency unit of the duo-cone loudspeaker is shown in Fig. 11. In the case of the high-frequency unit there are two additional compliances as contrasted to the low-frequency unit, namely, the compliance of the chamber behind the cone and the compliance between the coil and cone. The mechanical impedance at the voice coil, assuming the latter compliance, to be zero is given by

$$z_{MT} = r_{MS} + r_{MA} + j\omega m_{C1} + j\omega m_{C2} + j\omega m_A - \frac{j}{\omega C_{MS}} - \frac{j}{\omega C_{MC}} \quad (9)$$

where r_{MS} = mechanical resistance of the suspension system, in mechanical ohms
r_{MA} = mechanical resistance of the air load, in mechanical ohms,
m_{C1} = mass of the voice coil, in grams
m_{C2} = mass of the cone, in grams
m_A = mass of the air load, in grams
C_{MS} = compliance of the suspension system, in centimeters per dyne, and
C_{MC} = compliance of the air chamber behind the cone, in centimeters per dyne.

The efficiency, from Eqs (*3*), (*4*), and (*9*), is

$$\mu = \frac{(Bl)^2 r_{MA}}{(Bl)^2 (r_{MC} + r_{MA}) + r_{ED} [(r_{MC} + r_{MA})^2 + x_{MA} + x_{MC1} + x_{MC2} + x_{MS} - x_{MC}] 10^9} \times 100 \quad (10)$$

where r_{MS} = mechanical resistance of the suspension system, in mechanical ohms
r_{MA} = mechanical resistance of the air load, in mechanical ohms
$x_{MA} = \omega m_A$ = mechanical reactance of the air load, in mechanical ohms
$x_{MC1} = \omega m_{C1}$ = mechanical reactance of the voice coil, in mechanical ohms
$x_{MC2} = \omega m_{C2}$ = mechanical reactance of the cone, in mechanical ohms
$x_{MS} = \dfrac{1}{\omega C_{MS}}$ = mechanical reactance of the suspension system, in mechanical ohms, and
$x_{MC} = \dfrac{1}{\omega C_{MC}}$ = mechanical reactance of the air chamber behind the cone, in mechanical ohms.

The cone diameter of the high-frequency unit used in the duo-cone loudspeaker is 2 in. The mechanical resistance and reactance characteristics of the elements of the vibrating system are shown in Fig. 10. For the air load upon the cone it is assumed that the large cone

forms a conical horn. The mechanical resistance of the suspension system is 3600 mechanical ohms. It will be seen that mechanical reactance caused by the air chamber behind the cone is three times the

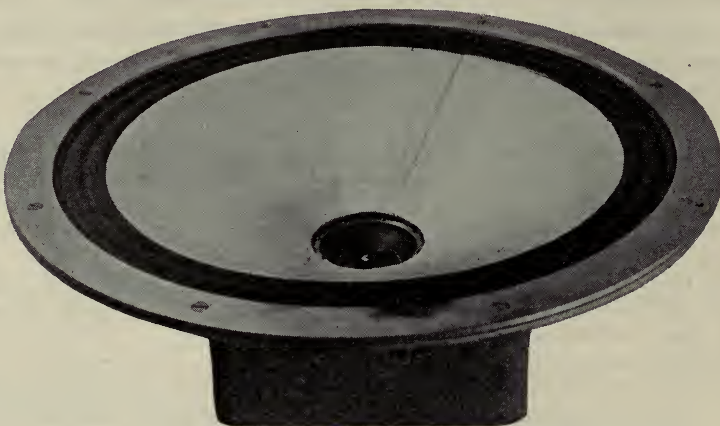

FIG. 12. A photograph of a duo-cone direct-radiator loudspeaker.

mechanical reactance resulting from the suspension system. Therefore, in the range where the compliances are the controlling mechanical reactances the compliance caused by the air chamber is the controlling compliance. This expedient reduces the distortion caused by

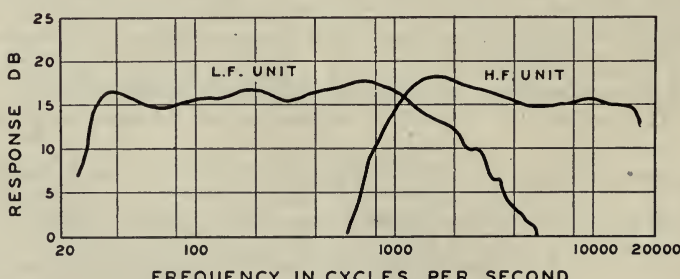

FIG. 13. Response frequency characteristics of the low- and high-frequency units of the duo-cone loudspeaker mounted in a large baffle.

a nonlinearity of the suspension system. The efficiency characteristic is shown in Fig. 10. It will be seen that the efficiency falls off about 10,000 cycles. This results from the fact that the system is mass controlled and the radiation resistance does not increase as the square of

the frequency above 10,000 cycles. By introducing a compliance, C_{M1}, between the voice coil and cone the effective mass of the system is reduced and uniform efficiency is maintained to 15,000 cycles as shown by the dotted efficiency characteristic of Fig. 10.

The combination of the low- and high-frequency units as outlined should yield uniform output from 30 to 15,000 cycles. A photograph of an experimental duo-cone loudspeaker having the constants given in this section is shown in Fig. 12.

Response Frequency Characteristics.—The measured response frequency characteristics of the low- and high-frequency units of the duo-cone loudspeaker mounted in a large flat baffle are shown in

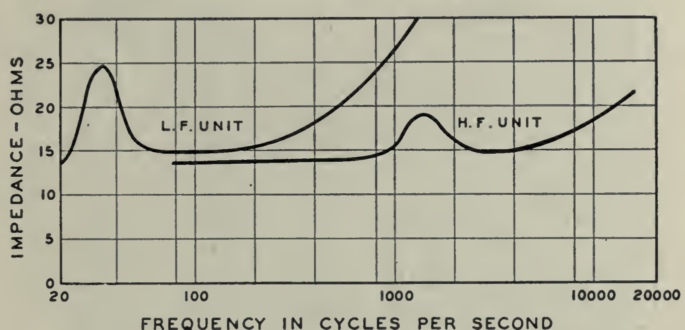

FIG. 14. The electrical impedance frequency characteristics of the low- and high-frequency units of the duo-cone direct-radiator loudspeaker.

Fig. 13. These characteristics are in substantial agreement with the efficiency characteristics of Fig. 10. The response frequency characteristics in a phase inverter cabinet will be considered in a later section.

Cross-Over Network.—The cross-over network is an important consideration in a direct-radiator loudspeaker. In the design of any two-unit loudspeaker, when there is considerable path length between the two units, a relatively sharp cross-over network is required in order to prevent destructive interference between the two units in the cross-over region. In the duo-cone loudspeaker, since the large cone is a continuation of the small cone, the cross-over frequency range need not be confined to a narrow band because the two cones vibrate as a single cone in this frequency region. This fact makes it possible to use a very simple cross-over network. The elec-

trical impedance characteristics of the low- and high-frequency units of the duo-cone loudspeaker are shown in Fig. 14. The inductance of the large low-frequency voice coil is large. As a consequence, it is not necessary to use an inductance in series with the low-frequency

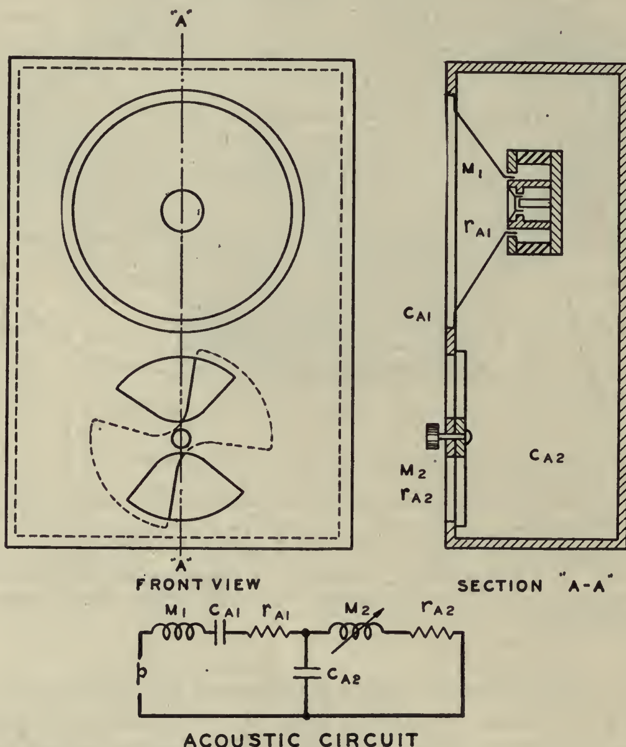

FIG. 15. Front and sectional views and the acoustic circuit of the acoustic phase inverter used with the duo-cone loudspeaker. In the acoustic circuit: M_1, C_{A1}, and r_{A1}, the inertance, acoustic capacitance, and acoustic resistance of air load and cone and coil of the loudspeaker unit; M_2 and r_{A2}, the inertance and acoustic resistance of the port; C_{A2}, the acoustic capacitance of the cabinet volume.

unit to reduce the current at the high frequencies. The only external element required for the cross-over network is a condenser in series with the high-frequency unit to limit the current through the high frequency unit at the low frequencies. The cross-over frequency in this system extends over about two octaves. However, as pointed

out before, this is not objectionable because in the overlap region the two cones vibrate as a single cone.

Phase Inverter with a Variable Port.—The preceding considerations have been concerned with the performance of the duo-cone

FIG. 16. Photograph of the duo-cone direct-radiator loudspeaker mounted in a phase inverter cabinet with the variable port with the grill removed.

loudspeaker operating in a large flat baffle. The large flat baffle is not a practical mounting arrangement for general applications. A cabinet is the conventional housing for direct-radiator loudspeaker systems. It is the purpose of this section to consider a phase inverter-type cabinet suitable for the duo-cone loudspeaker.

The term "phase inverter loudspeaker" is used to designate a system consisting of a loudspeaker mechanism mounted in a closed cabinet with an opening or port which augments the low-frequency response by the addition of the sound radiated from the port. The reason that

FIG. 17. Photograph of the complete duo-cone loudspeaker.

the addition of the port augments the low-frequency response is because the particle velocity of the air in the port is in phase with the velocity of the cone.

The amount of low-frequency accentuation required for a particular condition of reproduction depends upon the program material, the

room in which the sound is reproduced, *etc.* Therefore, it is desirable to provide a variable means for adjusting the low-frequency response to a loudspeaker. It is the purpose of this section to describe a phase inverter-type cabinet with a variable port.

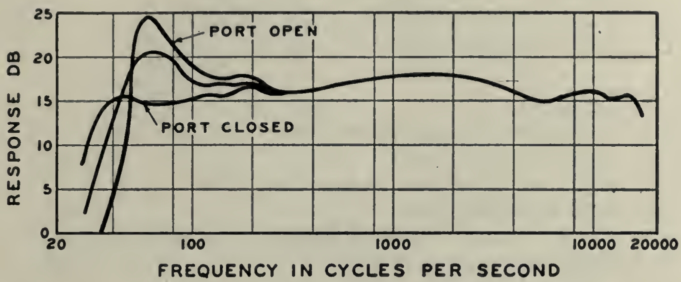

FIG. 18. Response frequency characteristics of the duo-cone direct-radiator loudspeaker unit operating in the phase inverter cabinet of Fig. 15 for various openings of the port.

The acoustic circuit of the system shown in Fig. 15 shows the action of the acoustic phase inverter. When the port is closed, the inertance $M_2 = \infty$, the action is the same as that of a completely enclosed cabinet. If the inertance of the port is approximately equal to

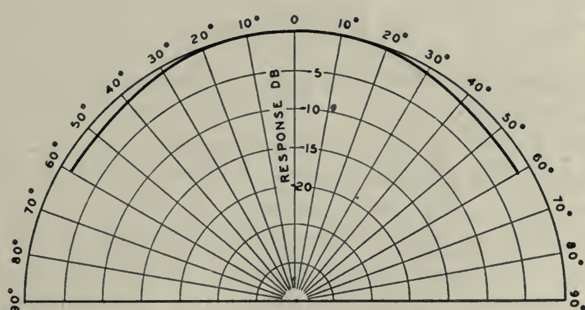

FIG. 19. Directional characteristic of the duo-cone direct-radiator loudspeaker at 1000 cycles.

the inertance of the cone the low-frequency response will be accentuated. The performance can be deduced from the acoustic circuit as follows:

The volume current in z_{A1} is given by

$$\dot{X}_1 = \frac{p(z_{A2} + z_{A3})}{z_{A1}z_{A2} + z_{A1}z_{A3} + z_{A2}z_{A3}} \tag{11}$$

where $z_{A1} = r_1 + j\omega M + \dfrac{1}{j\omega C_{A1}}$,

r_{A1} = acoustic radiation resistance on the cone,
M_1 = inertance of the cone and the air load, and
C_{A1} = acoustic capacitance of the cone,
$z_{A2} = \dfrac{1}{j\omega C_{A2}}$,
C_{A2} = acoustic capacitance of the cabinet volume,
$z_{A3} = r_{A2} + j\omega M_2$,
r_{A2} = acoustic radiation resistance of the cone,
M_2 = inertance of the port,
p = $ABli$ = sound pressure which drives the acoustic system,
B = flux density in the air gap,
l = length of conductor in the air gap,
i = current in the voice coil, and
A = area of the cone.

The volume current in z_{A3} is

$$\dot{X}_3 = \frac{p z_{A2}}{z_{A1}z_{A2} + z_{A1}z_{A3} + z_{A2}z_{A3}}. \tag{12}$$

The total power radiated is given by real part of

$$P = r_{A1}\,\dot{X}_1^2 + r_{A2}\,\dot{X}_3^2. \tag{13}$$

Eq (*13*) shows the effect of the port in altering the response in the low-frequency range.

A photograph of the duo-cone loudspeaker mounted in a phase inverter cabinet with the grill removed is shown in Fig. 16. The same cabinet with the grill in place is shown in Fig. 17.

The measured response frequency characteristics of the duo-cone loudspeaker operating in a phase inverter cabinet are shown in Fig. 18. These characteristics show the effect of the port opening upon the response and also show that the response is uniform in the overlap region.

Directional Characteristics.—The directional characteristics of a loudspeaker used for monitoring and high-quality sound reproduction should be substantially independent of the frequency over at least a total of 90 deg. The directional characteristics of a cone loudspeaker are a function of the frequency. At the low frequencies

where the dimensions are small compared to the wavelength the system is nondirectional. When the dimension of the cone becomes comparable to a wavelength the system becomes directional. Above this

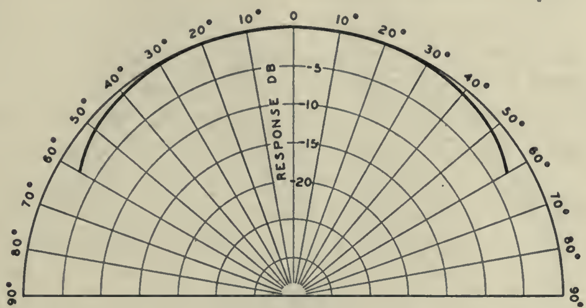

FIG. 20. Directional characteristic of the duo-cone direct-radiator loudspeaker at 3000 cycles.

frequency the directional pattern becomes progressively sharper with increase in the frequency. The directional pattern of a cone is also a function of the cone angle. This is because of the finite transmission of sound in the cone. By increasing the angle of the cone the directional pattern becomes broader at the higher frequencies. Relatively

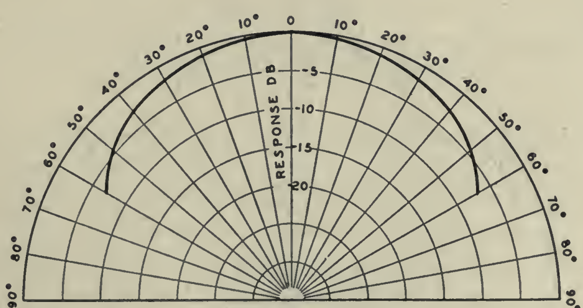

FIG. 21. Directional characteristic of the duo-cone direct-radiator loudspeaker at 6000 cycles.

wide angle cones were used in both the low- and high-frequency units of the duo-cone loudspeaker in order to obtain uniform response over a total angle of 90 deg up to 15,000 cycles. The directional patterns for 1000, 3000, 6000, 10,000, 13,000, and 15,000 cycles are shown in Figs. 19, 20, 21, 22, 23, and 24. The directional pattern is practically

nondirectional over the 90 deg angle below 1000 cycles. Referring to the directional characteristics it will be seen that the directional patterns show very little variation over an angle of 90 deg over the frequency range to 15,000 cycles.

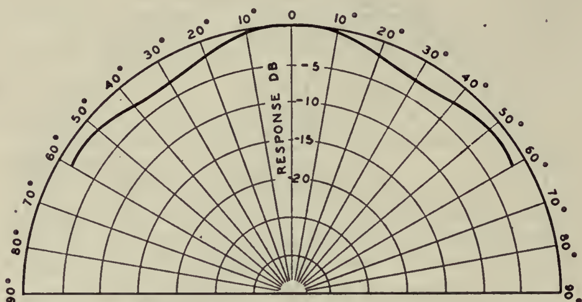

Fig. 22. Directional characteristic of the duo-cone direct-radiator loudspeaker at 10,000 cycles.

Nonlinear Distortion.—Nonlinear distortion occurs when a nonlinear element is present in a vibrating system. The outside suspension system is one nonlinear element in a direct-radiator loudspeaker. The stiffness is not a constant but is a function of the

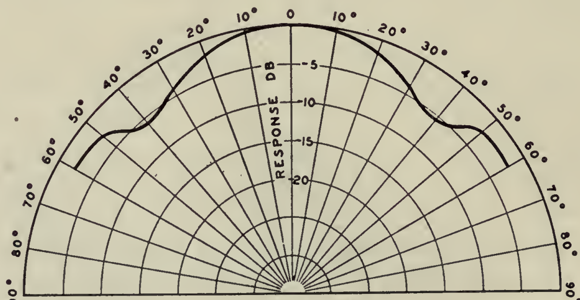

Fig. 23. Directional characteristic of the duo-cone direct-radiator loudspeaker at 13,000 cycles.

amplitude and, in general, increases with larger amplitudes. The theoretical and experimental considerations of nonlinearity in a direct-radiator loudspeaker have been considered elsewhere[3] and will not be repeated here. The conclusion of this investigation was that the nonlinear distortion caused by the suspension system may be elimi-

nated by placing the fundamental resonant frequency of the loudspeaker at the lower limit of the reproduction frequency range. Above the fundamental resonant frequency, the velocity of the cone is not appreciably affected by the suspension system because the mechanical reactance resulting from the compliance of the suspension system is small compared to the mechanical impedance of the remainder of the system. In this loudspeaker the fundamental resonant frequency of the low-frequency unit of the duo-cone loudspeaker was placed at 30 cycles. Under these conditions, the nonlinear distortion caused by the suspension system was minimized.

Another nonlinear element is the cone. In the range from 100 cycles to 1000 cycles nonlinearity of the cone produces both har-

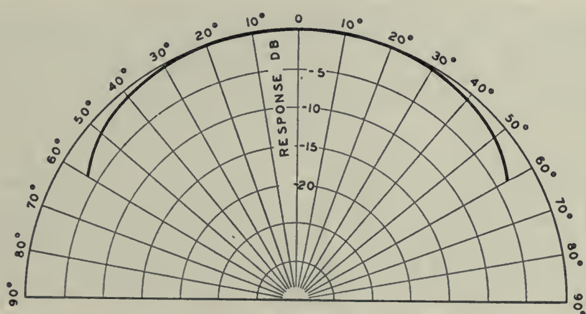

FIG. 24. Directional characteristic of the duo-cone direct-radiator loudspeaker at 15,000 cycles.

monic and subharmonic distortion. Since the range from 100 to 800 cycles contains the maximum power in both speech and music it is very important that the distortion be reduced to a minimum in this range. This can be done by employing a very rigid cone. In order to obtain sufficient rigidity to insure low distortion it was necessary to make the thickness of the cone about two and one-half times that of the conventional cone. This increased the rigidity by a factor of about 15 times.

Inhomogeneity of the flux density through which the voice coil moves is another source of distortion. This type of distortion can be eliminated by making the summation of the product of each turn and the flux density associated with that turn independent of the amplitude. This requirement was satisfied by making the voice coil large and slightly longer than the air gap. In order to obtain reasonable

efficiency with the heavy cone it is necessary to employ a heavy voice coil. A voice coil of 25 grams was used in this loudspeaker which is about 25 times the mass of the voice coil used in console-type radio loudspeakers.

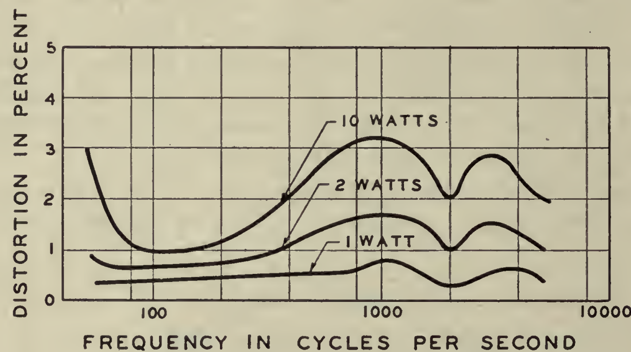

FIG. 25. Second harmonic distortion frequency characteristics for 1-, 2-, and 10-w input.

In the case of the high-frequency unit of duo-cone loudspeaker, the nonlinear distortion caused by the suspension system was minimized by making the stiffness of the space behind the cone the controlling

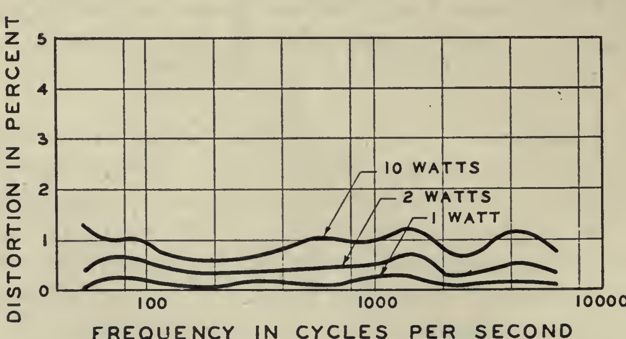

FIG. 26. Third harmonic distortion frequency characteristics for 1-, 2-, and 10-w input.

mechanical impedance. (See section on Theoretical Considerations.) For example, the resonance of the high-frequency unit without the back enclosure occurs at 750 cycles. With the back enclosure as used in the duo-cone loudspeaker the resonant frequency is 1500 cycles.

With the above expedients the nonlinear distortion in the duo-cone loudspeaker is quite low as shown in Figs. 25 and 26. The average input for normal monitoring and listening use is about 100 to 200 milliwatts which means that under these conditions the distortion is very small.

Transient Response.—The sounds of speech and music are of a transient rather than a steady-state character. Therefore, practically all the sounds which are reproduced by a loudspeaker may be considered to be of a transient nature. In view of this, the transient response of a loudspeaker is an important factor in sound reproduction. One way of testing the transient response of a loudspeaker is to apply a square wave current to the voice coil and record the output by

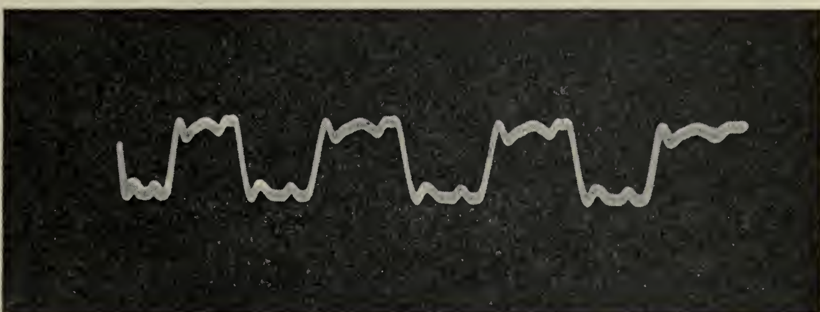

FIG. 27. Acoustic output of the duo-cone direct-radiator loudspeaker with an electrical square wave input of "900 cycles."

means of a microphone and cathode-ray oscillograph. For a test of this type it is very important that the microphone be capable of reproducing square waves. The velocity microphone is a mass controlled system in the frequency range above 15 cycles. Since the driving force is proportional to the frequency, the system can be replaced by a constant driving force and a resistance instead of mass element. The transient response of this system is perfect. A special velocity microphone was built in which the free field response as determined by reciprocity calibrations was uniform to within one decibel from 25 cycles to 16,000 cycles. The important frequency region from the standpoint of transient response in double unit loudspeakers is near or below the overlap frequency band. The response of the duo-cone loudspeaker to a square wave having a fundamental component of 900 cycles is shown in Fig. 27. It is not a perfect

reproduction of a square wave but is quite comparable to other audio elements covering this frequency range. It may be mentioned in passing that to obtain a semblance of square waves from a loudspeaker requires a very good acoustical system.

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[1] Olson, H. F.: "Elements of Acoustical Engineering," D. Van Nostrand Company, Inc., New York, N. Y., 1940.

[2] Olson, H. F.: "Dynamical Analogies," D. Van Nostrand Company, Inc., New York, N. Y., 1943.

[3] Olson, H. F.: "The Action of a Direct Radiator Loudspeaker with a Non-Linear Cone Suspension System," *J. Acous. Soc. Am.*, **16**, 1 (July 1944), p. 1.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

27, 7 (July 1946)	
The New Norwood Exposure Meter (p. 254)	R. A. Woolsey and C. H. Coles
27, 8 (Aug. 1946)	
Evolution of the Camera in Sound-Film Production, 1926–1946 (p. 276)	
Soviet Film Scenarios (p. 282)	D. Eremin
Sound and the Visual Image (p. 284)	H. A. Lightman

British Kinematograph Society, Journal

9, 2 (Apr.–June, 1946)	
Some Applications of Photography and Kinematography in War-Time (p. 39)	G. H. Sewell
The Past and Future Activities of the Society of Motion Picture Engineers (p. 43)	D. E. Hyndman and J. A. Maurer
Two New Sound Recording Films (p. 51)	I. D. Wratten

British Kinematograph Society, Proceedings of the Film Production Division

(Session 1945–46)	
The Evolution of Motion Picture Technique (p. 3)	W. M. Harcourt
Practical Sound Problems in Film Production. I. Production Requirements (p. 34)	J. J. Croydon
Location and Planning of Studios (p. 45)	H. Junge

International Photographer

18, 6 (July 1946)	
New Concentrated-Arc Lamp (p. 12)	G. S. Oslin
18, 8 (Sept. 1946)	
New Kodachrome 16-Mm Commercial Film (p. 9)	
Evolution of Motion Picture Technique (p. 11)	W. M. Harcourt
Kodak Etachrome Film (p. 18)	

International Projectionist

21, 7 (July 1946, Section 1)

The Retiscope Fiberglas Screen (p. 5) — P. Bethel

Video and the Somnolent Cinema (p. 12) — F. Waldrop and J. Borkin

21, 7 (July 1946, Section 2)

Studio Projection Engineering (p. 20) — A. Rost and W. McCormick

Evolution of the Carbon Arc for Projection (p. 24) — W. C. Kalb

Case History of the Simplex Projector (p. 33) — M. Stephan

If It Isn't on the Film (p. 36) — P. Mole

Projection Arc Lamps—Then and Now (p. 45) — H. H. Strong

Present and Future 16-Mm Projection (p. 48) — E. W. D'Arcy

Twenty Years of Horn Progress (p. 52) — W. W. Simons

Projection Room Design Advances (p. 54) — B. Schlanger

Motiograph: The Early Years (1896–1924) (p. 60) — A. C. Roebuck

21, 8 (Aug. 1946)

Basic Radio and Television Course, Pt. 25—Receiving Systems (p. 17) — M. Berinsky

Projectionist's Role in Sound Reproducer Development, 1926–46 (p. 22) — F. Lovett

The Photographic Journal

86B, 2 (Mar.–Apr., 1946)

The Scophony High-Speed Camera (p. 42)

RCA Review

7, 2 (June 1946)

An Experimental Color Television System (p. 141) — R. D. Kell, G. L. Fredendall, A. C. Schroeder and R. C. Webb

EMPLOYMENT SERVICE

POSITIONS OPEN

We are listing below additional positions available with the U. S. Public Health Service, Communicable Disease Center, as described on page 270 of the September Journal. Applicants should address inquiries to Personnel Officer, U. S. Public Health Service, 605 Volunteer Building, Atlanta 3, Georgia.

(7) CHIEF, EVALUATION SECTION, $4902 per annum. Requires a thorough knowledge of the evaluation of audio-visual aids as applied to the dissemination of information. Applicants must be able to devise programs of testing audio-visual aids. Must maintain liaison with personnel using same; must be able to advise on audience interpretation, attitude, motivation, dramatic presentation, for cinematic technology, upon the teaching impact; must supervise one or more part-time educators, and perform other related duties as assigned.

(8) PHOTOGRAPHER, MOTION PICTURE, $3397.20 per annum. Applicants must have a thorough knowledge of general motion picture and still photography and the ability to operate animation equipment. His experience should be of such productive nature as to indicate concisely the ability to perform the duties involved.

---

(9) CHIEF, WRITERS SECTION, $4149.60 per annum. Applicants must have had progressively responsible experience in the preparation of written material of a scientific or general nature for motion pictures, both general or training films, and other media of dissemination. Must be able to develop and prepare film continuity scripts and of collateral training material to accompany film production.

---

(10) CHIEF, ANIMATION SECTION, $3397.20 per annum, involving the ability to depict ideas of a scientific or technical nature for production through motion pictures and other audio-visual media. Supervises several animation artists.

---

(11) CHIEF, TRAINING AND PRODUCTION SERVICE, $8179.50 per annum. Applicants must be able to accept the responsibility for the development of the training and audio-visual production services of the Communicable Disease Center. Directs the program of production and distribution of all audio-visual training aids and the orientation and specialization training in public health. Advises with the Officer in Charge on program and policy formulation.

---

(12) FILM WRITER, $3397.20 per annum. Requires a knowledge of the development and preparation of film script in training film production. Must be able to prepare a shooting script adequate for the effective presentation of materials by audio-visual means.

New film production unit to be located at Athens, Georgia, needs film editor-writer and film director. Experience in 16-mm as well as 35-mm production desirable. Southern background or interest in South preferred but not essential. Write giving full details of experience, etc., to Nicholas Read, The National Film Board, Ottawa, Canada.

Photographer. Large manufacturer with well-organized photographic department requires young man under 35 for industrial motion picture and still work. Must be experienced. Excellent opportunity. Replies held in confidence. Write stating age, education, experience and salary to The Procter and Gamble Co., Employment Dept., Industrial Relations Division, Ivorydale 17, Ohio.

POSITIONS WANTED

Honorably discharged veteran with 10 years' experience in projection and installation of projection and sound equipment, both for booth and back-stage. Prefer to locate in California, Oregon or Nevada. For additional details write F.A.N., Box 113, Holley, Oregon.

Cameraman, honorably discharged Army veteran, desires re-enter industrial, educational production with independent producer or studio. Experienced in 35- and 16-mm color and black-and-white. References and complete record of experience available. Write, wire or telephone T. J. Maloney, 406 Oak St., Ishpeming, Mich. Telephone 930.

Sound Recordist. Former Signal Corps sound instructor and Army Pictorial Service newsreel recordist-mixer, 35-mm equipment. Honorably discharged veteran, free to travel. Write Marvin B. Altman, 1185 Morris Ave., New York, N. Y. Telephone Jerome 6-1883.

16-mm Specialist. Honorably discharged veteran with many years' experience, specializing in 16-mm. Linguist. Available for special assignments. Write J. P. J. Chapman, ARPS, FRSA, The Huon, Branksome Hill Road, Bournemouth, England.

Cameraman. Veteran honorably discharged from Air Force Motion Picture Unit desires to re-enter industrial, documentary, or educational film production. Experienced in 35- and 16-mm, sound, black-and-white and color cinematography. Single, willing to travel. Write S. Jeffery, 2940 Brighton Sixth St., Brooklyn 24, N. Y. Telephone Dewey 2-1918.

Experienced and licensed projectionist and commercial radio technician desires employment with 16-mm producer as sound recordist. Thoroughly familiar with principles and practices of sound-on-film recording. Write F. E. Sherry, 705 1/2 West San Antonio St., Victoria, Texas.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 NOVEMBER 1946 No. 5

CONTENTS

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THE NEWSREEL—ITS PRODUCTION AND SIGNIFICANCE*

Summary.—*The following symposium on the production and significance of the present-day newsreel was one of the discussions in the series of popular subjects arranged by the Atlantic Coast Section of the Society to promote a wider knowledge of motion picture industry techniques and practices. Newsreel operation in peace and war and a résumé of the details of production are described by staff members of Movietone News.*

EDITING THE NEWSREEL

DAN DOHERTY**

On behalf of our producer, Edmund Reek, it gives me sincere pleasure to welcome you here tonight. We have full knowledge and appreciation of the splendid contributions to the motion picture industry made by members of your learned Society and it is with a certain degree of temerity that we stand before you to tell you something about our little segment of motion picture making.

Screen journalists believe that the newsreel is one of the most vital units in the industry, but for all that, we are often neglected and sadly misunderstood. There is a tendency to too casual an acceptance of our noblest efforts and to too bitter criticism of our slightest foibles. One of the most rankling criticisms leveled at us is made by way of odious comparison, or I might put it "invidious comparison," in that it is based on a false premise.

Why, we are asked over and over again, cannot the newsreels present the news like newspapers, or like news magazines, or like picture magazines? To ask such questions, in our corporate opinion, shows a complete lack of understanding of a newsreel's function. While the newsreel at times can be the most complete reporter—wit-

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** Assignment Editor, Movietone News, New York.

ness recent UNO coverage, the battles of World War II, the assasination of King Alexander, Foreign Minister Barthou of France at Marseille, the Hindenburg disaster, the Jap attack on the *Panay*, the Pearl Harbor disaster—it cannot cover every item presented in the *New York Times*, or *Time* magazine, or *Life*, or the *Reader's Digest*.

The newsreel editor cannot, for many reasons, attempt to cover all the news. In the first place, the cost of keeping a camera staff capable of the noble effort would be prohibitive. In the second place, what would we do with it when we had it? Newsreel presentation time in theaters is limited. The newsreel editor has at most 1800 ft a week in which to present the news of the world!

By this confining fact alone his task is, therefore, not one of attaining total coverage but of selection, and selection based on an intimate knowledge and understanding of the medium.

But now I hear our critic saying, "Well, if that is so, why select all the trivia that newsreels are notorious for presenting, and why all those hardy annuals that year after year crash their way to the screens of the world via the newsreel releases?" Well, gentlemen, there you step on our pet corn, and we plead guilty. But there are extenuating circumstances, as I shall describe.

In the first place, a lot of the hardiest annuals are of national interest—the horse races, football games, world baseball series, Rose Bowl, Mardi Gras, *etc.* On occasion we have taken rein and passed up covering one or another of these stories. The howl which arose from exhibitors over our neglect would put a pack of wolves to shame. A given section of the public likes to see these well-advertised spectacles and all we can do is give it to them. You should see our mail with requests from exhibitors for stories of sectional interest only. For instance, exhibitors in the Michigan area want that hardy annual from Holland, Michigan, which shows the goodly descendants of those highly sanitary Dutch burghers turning out en masse to clean their city streets. This is picturesque only the first time you see it, but Michiganders expect it every year. So, we make a special of it for that territory. Almost every section of the country has a fête or celebration of this kind that the populace thereof thinks as much of as do the Michiganders about their exhibition of cleanliness.

Other trivia is partly our editorial responsibility. The policy of Movietone when there is a slack in the international picture is to present a balanced and entertaining reel. Therefore, we have our animal corner, our daffy Lew Lehr, our Donner Fashions, sport

features, "cheesecake" charm, and baby shows. You cannot always have Papal Consistories, with their medieval pomp and UNO meetings with their dramatic fireworks. You have to include a launching now and then, cover Washington doings, and so forth.

In fact, some of our greatest pictures have come from routine assignments. We had seriously considered passing up the arrival of the *Hindenburg* on the day it exploded because we had taken it arriving at Lakehurst many times without incident. Can you imagine what would have happened to our whole staff if we had not sent our man out there that day? We would all have been fired and justifiably so! An editor must have a sixth sense and anticipate things like that. Another incident happened during the very routine assignment of covering Mrs. Truman christening a plane. We got the laugh picture of last year. A subject we released on three ducks playing with a kitten was kept on many theater screens as long as eight weeks.

We are asked, "Why not controversial subjects?" I will be ready after this meeting to take suggestions from anyone who will tell me about a controversial subject that will fit into newsreel footage. Our newsreel policy is to be strictly objective, to let the camera tell the story. During the recent steel strike we had a prominent steel company thinking we were against them. Because of its far-reaching implication, when the strike broke we decided to cover it and sent men to the mills, *etc.* Then we went to the union involved and the company and asked for statements from the heads of each. We got one from the union but failed to get one from the company. Our release followed and then a call came from the company: the president would make a statement for us now. They were told politely that we did not want it then. We had three other talks in our reel coming up and the steel company was just backed off the front page as far as we were concerned. They swallowed hard, but took it. What else could they do—and for that matter, what else could we do?

That the newsreels do as good a job as they do with their limited staffs is a major wonder to me. However, we are by no means satisfied with ourselves and we are continually looking to improvement. About the future and television, I am sure you technically minded men are better informed than we, but we believe television to be our "oyster," that is, editorially. We have developed the techniques of covering news for motion and sound, and whether the picture goes on

a theater screen or a television receiving set, we know how to get it there with the greatest efficiency. You men have made the machines to do it—we think we have the editorial acumen to use them. Mergenthaler did not run Horace Greeley or Charles Anderson Dana out of business.

We have many violent critics, but in high places we have a few friends. We have the sympathetic understanding of such executives as our own president, W. C. Michel, and our parent company's president, Spyros Skouras, its vice-president in charge of distribution, Tom Connors, and our chief production executive, Darryl Zanuck. All of these men take a lively interest in our affairs, are first to praise us when we are good, and are not bashful with criticism when they believe it is justified. One of the most sincere tributes ever paid a newsreel was made by our late president, Sidney Kent. I would like, in conclusion, to read it to you:

"The newsreel is a Gulf Stream flowing through the motion picture industry, warming it with its vigorous, ever-young spirit of enterprise.

"With a long record of accomplishments the newsreel has earned an enduring place on every theater program. It is the standard short reel—never failing to make its screen time memorable, instructive, and entertaining. Its multitudinous activities, always carried out with breathtaking speed, amaze and inspire those who know the difficulties of production.

"We have only to review the record of Movietone News in any given year to appreciate the perfection of newsreel organization.

"Editorially and technically Movietone News has been a thing of clarity and precision. Balanced, poised, daring, and courageous it has steered an honest course through the labyrinth that is the history it records.

"In every country in the world it commands respect for the strict impartiality of its policies, wherein no whit of its independence is sacrificed. We are pleased to congratulate its executives and associates on the newsreel for the unsparing zeal with which they carry on through the endlessness and unexpectedness of their task of reporting the news of the world."

And that, gentlemen, is the significance of newsreels. It makes me sick to see some producers and theater men cringe before cheap politicians when their industry commands such an influential journalistic arm that can call on the Bill of Rights to maintain its journalistic prerogatives of free speech.

FOREIGN EDITIONS

HARRY LAWRENSON*

As a newsreel editor, which I have been for about 25 years, both in the "silent" days and since "sound," my chief interest in what goes on behind all the knobs and dials, on both cameras and amplifiers, is simply what comes out, on and behind the screen, when I press the buzzer to the projectionist. As long as the picture is in focus and the "noises" sound good, I am happy. When the pictures are fuzzy or shaky, or when the noises come out "sour," I can always cuss the technical department! And that, now and again, can be a blessing in disguise, for when, *on rare occasions*, the picture or the sound track is not so good, people will notice *that*, but they do not think to criticize occasional poor *editing* of the picture they are looking at!

But perhaps you would be interested in what happens to our newsreel pictures *after* the cameraman, the soundman, the recording department, and the editors have finished with them. Movietone News, as you see it in the Roxy or any American theater, is only the first product. That same newsreel, or most of the items in it, is subsequently shown in no less than 47 foreign countries and in more than a dozen different languages! From New York, and from very well-equipped production centers in London, Paris, Sydney, Australia, Brussels, Belgium, Rome, and now in South Africa, regular weekly or twice weekly editions of the newsreel are prepared and released. Movie audiences in Canada, England, France, Italy, Sweden, Australia, India, and every one of the Latin American countries are very familiar with the words *Movietone News*, even if, on occasion, they do appear on the screen as "Actualities Parlante," "Actualidades Movietone," or "Foxuv Zvukovy Tydenk." We have estimated the weekly world audience of Movietone at over 200 million people. The 50 leading newspapers of the world do not have anything like that circulation, all together!

If the newsreel has developed in its world appeal, I am happy to say that camera development and sound recording have definitely kept pace. One of my fonder memories is of 1927 when the first "portable" recording outfit went overseas. I was in Paris at the time, editing our then silent Fox Newsreel, when two gentlemen—Ben Miggins and Eddie Kaw—descended upon me in a huge moving

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* Foreign Editor, Movietone News, New York.

van with the words *Movietone News* on its sides! I said a "portable" recording outfit advisedly, for when Miggins and Kaw explained this newfangled sound business to me, they kindly offered to take me along on some of their jobs. I soon found that they needed me to help lift and carry the half-ton cameras and amplifiers and stuff with which the truck was loaded! Yes, it was portable, if you had a strong back and a weak mind. That outfit, incidentally, made the first sound films of such people as Clemenceau, Foch, Mussolini, and the Pope.

Speaking of portability, I went along with the sound crew on one of those early sound recording jobs in Europe, and a young priest put his finger on what was then our number one problem. We arrived at a small parish church in a provincial village to film a colorful ceremony and festival. We arrived barely in time, and the young priest who was to officiate was in a dither because of the delay. As we started to unpack all the heavy boxes and gear and dump the stuff outside his little church, he became visibly more agitated. When he saw that still more boxes and batteries and things were yet to be unloaded, he approached me with a look of concern. "M'sieur," he said, "if you have to carry all that equipment into our little church, we'll never get started. Don't you think it might be better if I brought the congregation and the ceremony out here in the yard and you made your picture from your truck?"

Today, thanks to you gentlemen, all our cameramen carry Eyemos, and I understand the soundmen carry all their gear in a very small cigar box! That, incidentally, might account for the occasional aroma that seems to emanate from the sound track!

When we look back to those very early days of the motion picture, when an Akeley was the latest thing in cameras, and sound was something Al Jolson was dreaming about, we have really come a long way. Who would have thought then that a United Nations Conference held in New York would be faithfully reported in sight and sound, and that the pictures would be shown, for example, in London, by Movietone News, only two days after they were made. Who, indeed, in these days when presidents, kings, prime ministers, and politicians go out of their way to get in front of a newsreel camera and microphone, would not wonder at the time, not too many years ago, when a news sound outfit was looked upon as a toy that was not to be taken seriously, or perhaps even something to be carefully avoided lest the speaker's words of wisdom be only too faithfully recorded and

presented to the public as he really said them, if not exactly as he meant them!

When the French statesman Clemenceau was alive, fear of the recorded word was quite real. We had tried and tried to get the old man to give us a sound interview, but the answer was always the same. In French, or English, it was "Nothing doing." But, one day, the old Tiger finally consented to a camera interview in his garden. No sound, however!! That was the condition. So, newsreel men, being always the soul of honor, carefully planted a microphone and cables behind a row of cabbages and set up our camera. Mr. Clemenceau came out and in a fairly genial mood began to walk around the garden while we took his picture. After a little of this, one of our boys asked him to move in nearer to the camera for a close-up, carefully leading him to the spot where our "mike" was hidden. The sound recorder was ensconced in the truck some distance away and out of sight.

All was well until our guide started to ask Mr. Clemenceau, in an off-hand fashion, what he thought of the world situation. Mr. Clemenceau appeared to think for a moment and his face darkened. Then suddenly he raised his thick walking stick into the air. "This is what I think!" he shouted, and brought his stick crashing down into the cabbage patch, right where our microphone was hidden! Or at least where we *thought* it was hidden! From then on we always kept our gear in full sight—microphones were expensive.

On another occasion in Sydney, Australia, where I was assigned to start our Australian Edition of the newsreel, we had an illustration of the sort of thing that helps remove hair from editors' skulls. Our task was to get out an all-Australian newsreel every week, and in a country where important news just does not happen every day that was quite a job. We managed to get out the reel for the first few weeks by running subjects somewhat longer than we might here, padding them a little, so to speak, and then came the inevitable. It was make-up day. We had to go to press that night and I needed 200 ft more.

I called the boys together—we had two sound cameras and one silent—and dispatched all three of them to go out and film something, anything; I had to have enough footage to fill up a newsreel. One went off to track down a talking bird about which he had heard. Another went to a union leader to try and get a statement on a threatened strike, and the silent cameraman went down to the

beach to look for a possible bathing girl picture. I was desperate! I went to the corner pub to get a drink. Some hours went by and eventually all three cameramen returned, each with the same report—nothing to photograph! By that time, however, *I did not mind.* The studio had caught fire and burned down while they were gone! And we did not have even a shot of our own plant going up in flames! Dog bites man!

I really have not a great deal either technically or scientifically to contribute to this session. But I will add this, in closing: Every week, when I receive my pay check for editing Movietone News, I say, "Thank heaven for the Motion Picture Engineers!"

WOMEN'S FASHIONS

VYVYAN DONNER*

Movietone News fashion subjects are miniature productions. In proportion, as much time and effort go into their make-up as goes into the preparation of a feature picture. We often spend weeks in preparation for a one-minute subject, and we spend a complete eight-hour day of shooting to get a one-minute subject on the screen. The whole world is tapped for ideas; and sets are especially built on which to present them. Girls are interviewed by the hundreds, and finally picked for their beauty and charm, poise and personality, figure and smartness.

For their movie appearance their make-up is as carefully put on as a Hollywood star's. Our cameramen light them to their best advantage, so that both girl and gown are exquisitely set forth in all their beauty. Every effort is used to make the newsreel fashion clip a small bit of perfection, from news and subject matter, suitability of set and location, and on up to the height of feminine American Beauty.

I work with the finest, most brilliant American designers, and bring their designs before the eyes of the world, showing American taste, American settings, American girls, and the "American look" to some hundred-million moviegoers.

In normal times, we make about one fashion picture every ten days. The commentary is translated at once into Portuguese and

* Women's Editor, Movietone News, New York.

Spanish, and shipped to all the sister Republics of Latin America. The fashions are then sent abroad for translations into French, German, Swedish, and all the other languages.

THE FILM LIBRARY

BERT HOLST*

Situated on the top floor of the Movietone News building is the Film Morgue or, to be more official, the Movietone News Film Library over which I preside. Few people in the news business have any idea of the true importance of this unpublicized department with its history in cans. As of this day there are stored in our vaults approximately 42 million ft of negative scenes shot all over the world, from the North to the South Poles, from every conceivable angle—ground, air, and underseas.

This film is carefully catalogued with a simplified but all-informative cross index, which allows us to put our hand on any given foot of film in the shortest possible time.

Thirty-two fireproof vaults store this film. Because of space limitations in addition to the millions of feet already mentioned, there are other millions in our out-of-town vaults at Ogdensburg, New Jersey. This latter footage we consider as the most unlikely to be called for by our own company, or by the other clients who use our library for stock shots.

We also have a sound library containing every conceivable sound or a good facsimile of any sound. This is also catalogued in our simplified system and before you could say "Jack Robinson" we could give you anything from an artillery barrage to a Bronx cheer.

One of the greatest worries of a film librarian is that old bogey, fire hazard. A constant vigilance must be maintained where so much inflammable film is kept. Extreme temperatures, either hot or cold, are always a problem with us and at such times we must be careful of gas accumulations and see to it that the entire vault spaces are properly aired. We must also guard against dampness that rots film and dryness that shrinks it. Keeping this invaluable collection of canned history in a good state of preservation means maintaining as near as possible a constant temperature.

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* Librarian, Movietone News, New York.

From our library we yearly supply the industry with millions of feet of stock shots. Practically every West Coast production company uses our facilities, that is, when they do not conflict with our service to our parent company, Twentieth Century-Fox Film Corporation and of course our own newsreel and short subject department.

I do not have time to tell you of the demands made on us which we satisfy in the majority of cases. Being film men you could easily imagine what these are. Some are really tough to fulfill but we manage to do them most of the time. However, there are limits to our ingenuity and we are stumped occasionally. For instance, here are some actual requests we have received from some of our clients.

"Have you a shot," we were once asked, "of an English railroad train running without lights during a blackout?"

Another time a lady editor seriously wired for—and this is the exact description she sent us—two love doves cooing, one gets vexed and draws away, the other seems to pine.

A West Coast producer once asked us for an alligator waving an American flag!

A religious organization in the process of making a biblical picture wired us, "What have you got in your library on Abraham and Moses?"

A big powder manufacturing company making a commercial, wired us to send them a 2-ft shot showing a close-up of the impact of an explosive shell hitting an iceberg.

A famed explorer wishing to illustrate the fiction he dishes out in his lectures wrote us that we would greatly help his film presentation if we could supply him with a pelican diving for a fish; camera to follow him under the water; pelican to catch school of fish; fish swimming in pelican's bill.

Then, as innocently as a newborn babe, another West Coast producer wired us for "A Wednesday afternoon scene—Landscape." This is a complete description of his request!

Of course there are many requests for sound effects, legitimate and otherwise, but I actually got this one: "Can you send us the sound of a moccasin on soft snow?"

That, gentlemen, is a little about the Movietone News Library.

THE FIELD UNIT

JACK GORDON*

An assignment to cover a national political campaign offers an opportunity to explain the many problems and obstacles encountered by a newsreel unit in the field. As I was "Mr. Newsreel" with one of the candidates on the last campaign I can tell you this is so.

Shortly after the conventions, I was appointed, at the suggestion of our Producer Edmund Reek (after he had been asked about it by the Republican National Committee), to take charge of the newsreel coverage of the campaign and to be the liaison between all the newsreels and the Republican Committee. On paper it looked easy and a nice chance to see the country at the expense of the Republican National Committee. Well, you live and learn. The only things I saw were stars when our special train collided with the rear end of another train.

To start, my first duty was to make arrangements on the campaign train for a representative from each of the reels. When we were ready to depart we had only a rough itinerary. First, Philadelphia, next Louisville, then across the country to Washington, then Oregon, California, and then back east again. At every major stop plans had to be made for camera positions in each of the many auditoriums where Dewey was to speak. Lights had to be rented or bought and set up, and last but not least unions in different localities had to be contacted so that there would be no difficulties from that end.

Each auditorium and stadium was different, which meant many problems. Some had balconies and some did not. To offset this, platforms were built for each place large enough for all the newsreelmen to work comfortably. And lighting these huge places was always a problem. Some of these cities, where addresses were to be made, did not have sufficient equipment to supply our lighting needs.

We had to call New York, Chicago, and California to furnish this equipment; big city coverage was difficult, but easier to handle than stops enroute. When the special train stopped at some small town, the local populace would be out at the station en masse. Of course, our candidate would be prevailed upon to make a short address. Plans for these platform addresses would be announced but a short time before the train would be in the station. Cameramen would

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* Unit Director, Movietone News, New York.

have to be ready to jump off the train and rush back to the observation car, fight their way through the crowds to get a good location, and be ready when the candidate appeared. At no time could the cameramen afford to let the candidate appear without safeguarding themselves by being on the spot with their cameras. None could foresee what might occur; witness the shooting of Mayor Cermak when an attempt was made in Florida to assassinate President Roosevelt.

In all of the major cities where the candidate campaigned the local authorities would arrange for quite a celebration and parade from the station to his hotel headquarters. This route had to be covered and arrangements had to be made for a special automobile to carry the cameramen at the head of the parade. Although this arrangement was agreed upon with the candidate and his staff it very often happened that the camera car would have to battle against being pushed out of the parade. Passes, police cards, and other identifications meant nothing to some of them. There is a perpetual feud between newsreel men and police. The constabulary always have their own ideas as to where the newsreel fits in. It was very important that the candidate be covered completely but it meant constant fighting to do it.

There is never a dull moment for the hard-working cameraman. He never knows what the morrow will bring for him. Some local assignment, city fathers pinning a medal on visiting heroes, a political speech, amateur boxing or basketball, Atlantic City beauty pageant, or a trip around the world. Perhaps just a fire that will keep him on the job all night and day, or a strike. Whichever the case, it will be on film, and the next day he will be back for more.

THE NEWSREEL CAMERAMAN

WALTER McINNIS*

Fifty years ago this October, Hammerstein's Olympia Music Hall rang to the cheers of an enthusiastic audience as President McKinley's Inaugural Parade was re-enacted in all its pomp on a motion picture screen.

In 1927, the Fox-Case Corporation launched its famous Fox Movietone News. It was instantly popular and the public who had become

* Cameraman, Movietone News, New York.

sound conscious overnight, received it with great acclaim. Before long the silent-type newsreel became antedated and just as quickly so did the silent type of coverage suffer a momentary lapse. All newsreel stories were covered with the prime thought in mind, "How is it for sound?" This was purely a transition period. The newsreels had found their voice, but had not yet learned to talk.

Public acclaim for the sound newsreels was not to be denied. Before long all five major newsreel producing companies were operating sound trucks throughout the world, although none quite so extensively as Fox Movietone. It surely seemed as if the day of the silent camera had waned, but already the pendulum had reached the limit of its swing and was enduring that split-second battle with inertia before returning. In other words, motion pictures with sound were no longer newsworthy *just because they had sound.* Now, the sound had to be justified, and thus the newsreel commentator was born. It soon became apparent that many newsreel shots could be covered "MOS"—or in newsreel parlance, "mitout sound"—and joyfully, cameramen rushed to their respective attics and reverently dusted off the old silent cameras.

Aided and abetted by the newsreel editors who once more had become "coverage conscious" the pendulum raced back across its arc with increased momentum while the amount of field-recorded sound that was heard in the newsreel became reduced to nearly the vanishing point.

During this period many improvements in sound camera equipment were made by the Wall Camera Company of Syracuse. A new compact self-contained camera, comparable in weight to a silent Mitchell camera, and requiring a light 12-v storage battery for its operation, was delivered to Movietone cameramen. It had the first of the popular *D*-type intermittent, a rack-over arrangement for critical focusing through the objective lens, and a right-side-up finder. This camera could be used with a 400-ft magazine as well as the 1000-ft type, an important weight decreasing factor. All of the restrictions imposed upon cameramen by the use of the old-type sound camera equipment were eliminated with this new camera. The sound equipment, too, had become very portable and movement became almost as unrestricted as with the silent camera. Another important improvement was the Akeley gyrotripod permitting smooth "pam" and tilts coupled with ruggedness of construction. For nearly all types of stories this tripod is still unsurpassed.

Newsreels today show the result of 50 years of progress. No small tribute to the newsreel institution is the record of combat coverage in the last war. The pool of war correspondents of the five major producing companies was responsible for much of the documentary film which will provide the motion picture history of the war. Combat cameramen attached to the Armed Forces rapidly acquired the newsreel technique under the tutorship of many oldtimers in the business. In fact, at this office and at the *March of Time* Newsreel Cameramen School operated during the first year of the war, hundreds of fighting cameramen were put through these two institutions. The graduates in turn trained the great body of fighting cameramen who have given us the complete history of World War II in motion pictures.

In October 1929, in the pioneer days of sound newsreels, I was given an assignment to go to India on a tiger-hunting expedition. Before leaving, a rush call came for a lightweight outfit to make pictures with sound aboard the dirigible *Los Angeles* on a test run over Philadelphia and New York. We took off at 5:00 P.M. and made pictures of the crew's quarters and other interiors. Approaching New York approximately at 8:30 P.M., with the light not too good, we took a chance and made some night shots of the City. The Commander of the *Los Angeles* was good enough to describe the time and places we were passing over; his voice recorded exceptionally well, considering the drone from the motors. We were later complimented on the quality of the negative and sound, and were informed that these were the best night shots made over New York up to that time.

Our first jungle assignment was in Hydrabad, where our camera was placed on a platform built in a tree at a 15-ft elevation. The microphone was set where we hoped a tiger would make an appearance to kill a water buffalo or cow. This continued for nearly three months with only partial success—the tiger refused to co-operate.

We then moved to the native state, Cooch Behar, north of Calcutta. The Mahareni of Cooch Behar was very co-operative and we made several tiger hunts from elephants. In all we had 32 elephants. We were more successful on this enterprise. On our first trip into the jungles the two elephants mentioned before had quite a battle over a maiden elephant, and that nearly ended our hunt before we even got to our jungle location, but the mahouts appeased the elephants.

About 20 elephants would form a large circle and drive in any tigers or other animals that were encircled in the ring toward the fire line where we, the Mahareni, and her guests were set up. Our first

drive netted a huge black bear with two cubs clinging tightly to their mother's back. The huge bear came out of the jungle so close to my camera elephant that he became startled and reared back on his hind legs, and in turn gave me quite a scare not knowing whether he would crash back on me and the equipment. The elephant finally settled down and surprisingly enough we had some very good pictures with sound of the elephants trumpeting wildly and loudly. The Mahareni's guests made no attempt to shoot the bear because it is not considered sportsmanlike to shoot a mother bear with cubs.

In our next beat-in, we rounded up a leopard, and the following day we rounded up a large tiger weighing nearly 400 lb. This is really a sport of kings as one has to be an invited guest to take part in a hunt of this nature.

In April 1930 we returned to Calcutta. The city was in an uproar. The Ghandi riots had started; so instead of returning to New York we shot a lot of material in Calcutta, and then proceeded to Bombay where the fighting was more intense. We made thousands of feet of riot pictures.

NEWSREEL SOUND

WARREN M. McGRATH*

The wedding of sight and sound in motion pictures was pioneered in no small extent by newsreel soundmen and engineers. Since the remarkable sound picture record of Lindbergh's takeoff on the first Trans-Atlantic flight early in 1927, a small group of intrepid field soundmen have brought back a library of sounds and sound effects that should remain a lasting tribute to their skill, ingenuity, and daring. The few field soundmen who remain continue to record sound under acoustic conditions that would be the despair of the average studio mixer.

It was inevitable that newsreel sound should pass through an era of growing pains before settling down to a specific treatment acceptable to all major newsreel producing companies. Since early 1932, the commentary type of newsreel story has increased in popularity until today it is accepted as the most lucid manner in which to present

* Sound Engineer, Movietone News, New York.

current events. This, of course, has resulted in a steady decrease in the amount of natural sound recorded in the field and thus the work of the newsreel synchronizer has become increasingly important. It is through his efforts that commentary mixed with music and sound effects, and an occasional interpolation of natural sound, results in a pleasing composite sound track at a level constant throughout the reel and unvarying from week to week.

The newsreel synchronizer, or recording engineer, handles the final stage through which newsreel make-up proceeds. His work commences when the film has been edited, music carefully selected from a vast library of prerecorded tracks, and sound effects tracks and script all prepared in final form. The tools of his trade are:

(*1*) An acoustically treated narration stage, equipped with a pickup micro phone and a motion picture screen visible to the commentator and the mixer;

(*2*) Several film rerecorders, or film phonographs, used for the rerecording of music and sound effects;

(*3*) Several loop machines. These machines are rerecorders so arranged that a continuous loop of sound track can be run through them during the scoring of a picture and thus furnish a constant source of a particular sound, available to the mixer whenever required;

(*4*) Disk recorders and playbacks for the premixing of complicated sound tracks when required;

(*5*) A recording console with its associated amplifiers, mixers, and equalizers;

(*6*) A high-quality monitoring system;

(*7*) A film recorder;

(*8*) An interlock drive system which will furnish the motive power for all rerecorders, loop machines, projection machines, disk machines, and film recorders, and which will keep all of the machines being driven by the system in perfect synchronism.

All of this equipment is maintained at a consistent high efficiency. Routine measurements, gain runs, and film tests are compared with standard equipment data to insure a minimum of breakdowns and a maximum of quality. Spare equipment units and a jack panel provide a flexible means by which the mixer may substitute apparatus, cascade amplifiers, or introduce equalizers for a desired effect.

Newsreel subjects are infinite in their variety. A routine procedure for mixing sound can have no application here. Each subject must be handled with tact and discernment befitting its especial

nature. The editorial department furnishes the mixer with a "spot" sheet on which each scene of the newsreel subject is carefully listed in its proper sequence. The spot sheet also indicates the desired sound that is to be synchronized with the particular scene and the footage. A comparison between the narrator's script and the spot sheet will give a fairly close idea of the treatment the newsreel subject should receive.

Two music tracks are provided for most subjects. The tracks are prints of the same music negative but have "start" marks so placed that one is synchronized to start with the beginning of the picture and the other to finish with the end of the picture. The mixer must use a suitable spot during the recording to change over from the first music track to the second. This is usually done during sound effects, natural sound, or long periods of narration in order to mask the operation. Of course, careful note must be made of the key in which the particular part of the music track is played, as changing from one key to another is instantly apparent. This system of using two identical music tracks eliminates the necessity of having music passages recorded to a precise length.

The newsreel sound crew consisting of two soundmen, a projectionist, and the mixer, work as an efficient unit. Each man has his duties and co-operates with his fellow department members to insure a swift and efficient handling of the newsreel scoring. The mixer depends upon the efforts of the machine room soundmen to thread correctly the music and sound effects tracks in the rerecorders and loop machines, and properly to thread and "sync-mark" the recording film. The recordist, *i. e.*, the soundman in charge of the film recorder, must also keep a careful check on the over-all recording level and the recording lamp current; each man must carefully check the machines assigned to him to insure their smooth operation. The projectionist's duties are too well known to enumerate here.

One and sometimes two rehearsals are required before the timing and co-ordinating of all sound is mastered. During these rehearsals, the mixer must find time to check the tonal quality of the narrator's voice, his volume level, and the general level and synchronization of the sound effects that are to be used. Important, too, is the spotting of the story wherein the commentator and mixer carefully check the script for timing. Each line of copy must be spoken at precisely the spot for which it is intended and there must be a smooth transition from narration to field recorded dialogue when required.

Rehearsals completed, we are now ready for a take. A swift résumé of the sound to be used on the subject might indicate that two channels are required for music tracks, one for synchronized sound effects, one for the continuous running loop machine, one for the pick-up of field recorded sound from the picture film, and a narration channel. Six channels which the mixer must manipulate in an average time of less than two minutes and with only two hands.

All recording for our national newsreel is done by the double-system method wherein the sound is recorded on a separate piece of film than that used for the picture. For this type of recording, and as we use a variable-density type of recording, Eastman Type *1373* Fine-Grain Recording Positive is used. Excellent quality is obtained when developed to a density of 0.55 and a gamma of 0.55. After much experimentation we have determined that little is to be gained by the use of noise reduction when using this type of film. Although the film is used solely for the sound track, it has been found advantageous to print a picture image on it before developing in order to facilitate the work of the editorial department and to aid the final check on the sound recording work that has been done. The lavender picture used by the mixer and narrator in scoring is used for this purpose, and lining up the start mark on this with a corresponding one on the sound track enables the laboratory to print a backward, negative, "in-sync" image beside the sound track. At least once during the scoring session the mixer must check with the laboratory to assure himself that the sound track is properly exposed for density and gamma heretofore mentioned. For this purpose a small strip of unmodulated sound track is sent to the laboratory well in advance of the start of the evening's recordings. The report returned by the laboratory enables the mixer to correct the recording lamp current accordingly.

From the foregoing it can be seen that the recording engineer's responsibilities are many and varied. Equally important, however, is that sixth sense which for want of a better definition, can be called a sense of timing. Newsreel subjects being essentially fast-moving and of short duration, it is often necessary to bring in sound effects precisely on a frame. Then again, the time in which all recording must be completed is very limited. Although some lengthy subjects have taken as long as one hour to score, the average time taken by the recording room, from the start of rehearsals to the completed take, is less than 15 min.

It is not possible to discuss the many electronic and mechanical devices by which the recording room accomplishes the varied sound recordings which it is called upon to produce in the course of a single newsreel. Like any sound department, improvements are always under way at Movietone News. To Earl Sponable and William Jordan go unstinted praise in their constant pioneering in the electronic field. The installation of sound recording equipment at this studio remains as a tribute to their skill and forethought.

CHARACTERISTICS AND APPLICATIONS OF CONCENTRATED-ARC LAMPS*

W. D. BUCKINGHAM AND C. R. DEIBERT**

Summary.—*The concentrated-arc lamp is an arc lamp provided with permanent electrodes which are sealed into an argon-filled glass envelope. The light source is a sharply defined luminous disk on the end of a specially prepared zirconium oxide cathode. The radiation has a gray body distribution with the superimposed atomic spectra of zirconium and argon. In the various sizes of lamps now made the light-emitting spot ranges from 40 to 100 candles per sq mm in brightness and from 0.003 to 0.06 in. in diameter.*

Small-sized lamps furnish a close approach to a point source and have application in optical testing and demonstrating. Medium-sized lamps make increased detail rendition and depth of focus possible in microscopy and the photographic enlarger. Large-sized lamps are applicable in the field of projection.

The concentrated-arc lamp is a new type of light source that was invented just prior to the war and developed during the war under a contract issued through the Optics Division of the National Defense Research Committee. The new lamp is an arc lamp, but differs from the usual carbon arc in that it has permanent, fixed electrodes which are sealed into a glass bulb filled with an inert gas. The name "concentrated-arc" comes from a characteristic of the lamp which makes it possible to concentrate the arc activity upon a small portion of the electrode so as to produce a very high-intensity light source in the form of a luminous circular spot, which is fixed in position, sharply defined and uniformly brilliant.

A line of standard size lamps has been developed in 2-, 10-, 25-, and 100-w sizes. Pictures of these are shown in Fig. 1. Lamps have been made in sizes as large as 1500 w, but they are considered experimental as yet, and their designs have not been standardized. The actual physical sizes of the lamps shown in the picture range from the 2-w lamp, which is $^5/_8$ in. in diameter and 2 in. high, to the 100-w lamp which is $2^3/_8$ in. in diameter and 6 in. high.

* Presented May 9, 1946, at the Technical Conference in New York.

** The Western Union Telegraph Company, Electronics Division, Water Mill, N. Y.

The actual source of the light is a flat circular luminous disk that forms on the end of the specially prepared central wire, which is the negative electrode or cathode. The diameter of this disk in the 2-w lamp is only 0.003 in. As the current is increased, the spot grows larger so that a 100-w lamp has a spot 0.060 in. in diameter, while the spot of a 1500-w lamp is 0.375 in. in diameter.

With a 2-w concentrated-arc lamp in operation, it is difficult to believe that the source is but 0.003 in. in diameter because it is so bright that the eye sees it as a disk of light which is apparently $^1/_8$ in. or more in diameter. If a dense welding filter is put in front of the lamp, it is seen as a very tiny source.

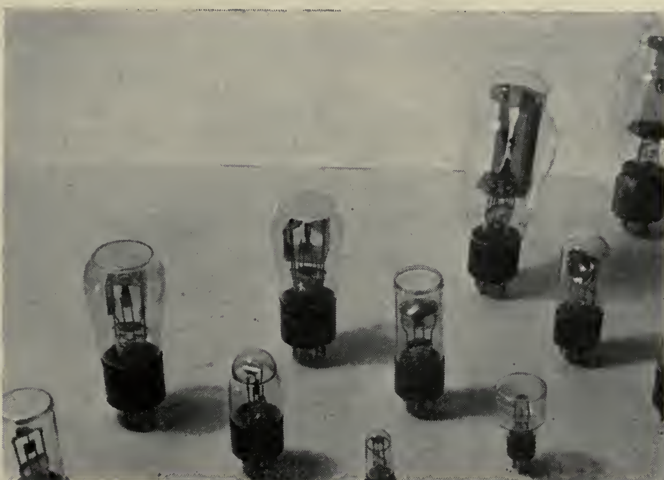


FIG. 1.

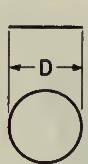
Some of the characteristics of the lamps are tabulated in Fig. 2. The brightness of the 2-w lamp is about 100 candles per sq mm. Ordinary tungsten filament lamps operate at about 10 candles per sq mm and have a life of 1000 hr. By increasing the current through tungsten lamps, they can be operated at brightnesses ranging up to 20 or 25 candles per sq mm but under these conditions, their life drops to 10 hr or less. Concentrated-arcs are thus several times brighter than tungsten lamps and have a longer life.

The 2-w lamps have an average life of 175 hr. Larger lamps last longer, 100-w lamps averaging 1000 hr. By average life it is meant that if a number of 100-w concentrated-arc lamps were started to-

gether on life test, half of them would be good at the end of 1000 hr. Since this is almost a year of continuous operation, and since life tests cannot be accelerated, such data are collected very slowly.

The tabulation of Fig. 2 shows the brightness of the positive crater of the ordinary carbon arc to be from 175 to 800 candles per sq mm, and the sun to have a brightness of 1600 candles per sq mm. The brightness of concentrated-arcs thus falls between that of tungsten filament lamps and that of the carbon arc.

The internal construction of a typical, concentrated-arc lamp is shown in the drawing of Fig. 3. The negative electrode or cathode is the unique element of the new lamp. It is made by packing zirconium



D	LAMP RATING
0.003	2 WATT
0.060	100 WATT
0.375	1500 WATT

	TUNGSTEN		CONC.-ARC	CARBON - ARC LOW HIGH INTENSITY		SUN
BRIGHTNESS CANDLES / MM^2	10	25	100	175	800	1600
LIFE-HOURS	1000	10	175 – 1000			

Fig. 2.

oxide into the open end of a tube which is made of tungsten, molybdenum, or tantalum, these metals being selected because of their high melting temperatures.

The positive electrode or anode, also made of a metal with a high melting point, consists of a simple sheet or plate which has sufficient radiating surface so that during operation, it will reach no more than a dull red heat.

These two electrodes are mounted in the bulb so that the exposed oxide surface of the cathode is but a few hundredths of an inch from and directly behind a hole in the center of the anode. This hole is slightly larger in diameter than the cathode tube and serves as a window for the emergence of light from the cathode.

After the bulb has been evacuated, it is filled with an inert gas, usually argon, to almost atmospheric pressure. The cathode is then

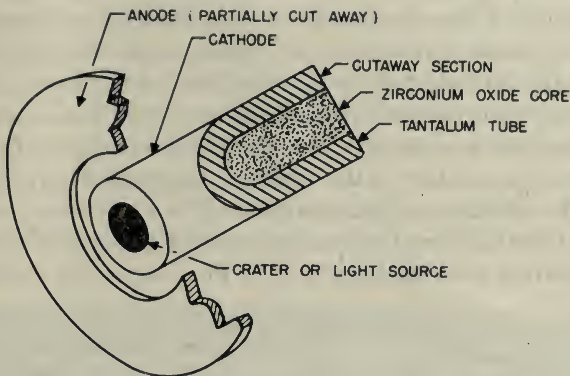


FIG. 3. Internal elements of the concentrated-arc lamp.

put through a "forming" process. To do this, a high potential direct-current source, with suitable current limiting resistors in series is connected to the electrodes so that an arc strikes between the anode and the metallic tube of the cathode. After a few seconds, the

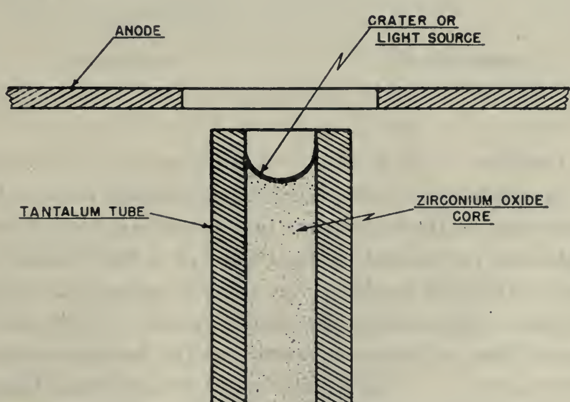


FIG. 4. Cross section of an old concentrated-arc lamp.

cathode tube becomes red hot and heats the zirconium oxide packed in it to a temperature where the oxide becomes electrically conductive. The arc then strikes between the anode and the oxide and the heat of the arc raises the temperature of the surface of the oxide to or above

its melting point of 3000 K. The molten oxide flows and bonds itself to the sides of the metal tube forming a smooth glassy surface.

In the molten state and under the intense ionic bombardment of the arc, some of the zirconium oxide is reduced or decomposed to metallic zirconium forming a very thin layer of this metal over the surface of the cathode. Zirconium metal is a better electron emitter at high temperatures than is the oxide, and it also has a lower melting temperature; thus, as soon as the metallic zirconium surface layer is formed, the temperature of the cathode drops slightly, and the underlying oxide solidifies and supports the film of molten metal on its surface. It is this film of molten metal which is the chief source of the visible radiation from the lamps. The film, once formed during manufacture, remains to be heated and become incandescent whenever the lamp is relighted. It is so thin that surface tension holds it to the oxide backing so the lamps may be burned in any position.

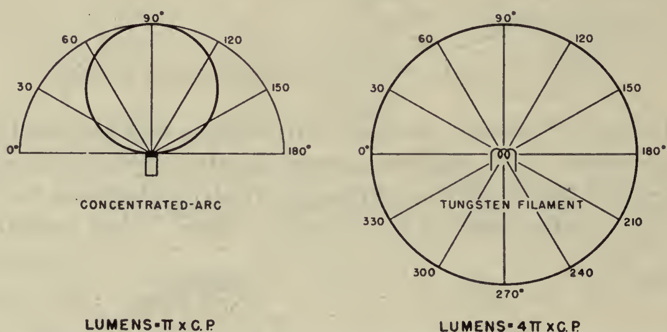


FIG. 5. Spatial distributions of concentrated-arc and tungtsen filament lamps

This light source, consisting as it does of a thin metallic film supported by a refractory backing, has several unique advantages. Ordinary tungsten filament lamps can be made to give more light if burned hotter, the radiation increasing as the fourth power of the absolute temperature. A small increase in temperature thus produces a comparatively large increase in radiation. This process is limited in the tungsten filament lamp by the melting point of tungsten, for if it is reached or even closely approched the lamp quickly burns out. Concentrated-arc lamps are not so limited. In these lamps, the incandescent metallic light source can be operated and is operated at a temperature which is above the melting point of the metal, thereby

producing light of a color quality similar to that which would be emitted by tungsten if it could be operated at a temperature at or slightly above its melting point.

A second advantage of the concentrated-arc is its life characteristics when operating at these high brilliancies. As the temperature of the filament of a tungsten lamp is increased, lamp life decreases because of evaporation of the filament material. Since the metal source of the concentrated-arc lamp operates in a molten condition, it might be expected that it, too, would evaporate.

Spectrograms taken of the portion of the arc stream very near the cathode show the presence of very strong zirconium lines. This in-

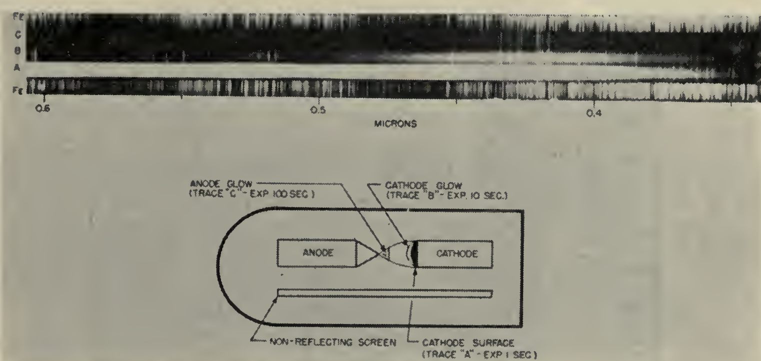


FIG. 6. Spectrogram of a 100-w concentrated-arc lamp. The diagram indicates in what part of the arc stream the various spectra originate.

dicates that some evaporation of free zirconium occurs and under the excitation of the arc, the characteristic spectrum is emitted. It is found, however, that in addition to the normal zirconium spectrum, the singly and doubly ionized zirconium spectra are also present. Furthermore, there is practically no zirconium found in any portion of the arc stream except that portion which is within a few thousandths of an inch from the cathode surface.

These phenomena are explained as follows: An atom of zirconium gains sufficient energy to leave the cathode surface and enters the cathode glow region of the arc which extends for a few thousandths of an inch from the cathode surface. Here, under the intense argon ion bombardment, the zirconium atom has one or more electrons knocked off of it, or in other words, it is ionized. In the normal atom,

the positive nuclear charge is just balanced by the negative charges of the surrounding electrons so the atom as a whole is neutral. When electrons are removed, as in the ionized atom, the atom is left with a positive surplus and thus has a positive charge and is attracted and drawn back to the negative cathode it just left. If any zirconium atoms do escape permanently from the cathode, they are replaced by reduction of the underlying oxide. As a result of these processes, the lamps have lives which are measured in hundreds of hours.

During the normal life of a concentrated-arc lamp, the amount of material evaporated from the cathode is so small and that little is so well distributed by the strong convection currents in the argon gas within the bulb that bulb blackening is not serious.

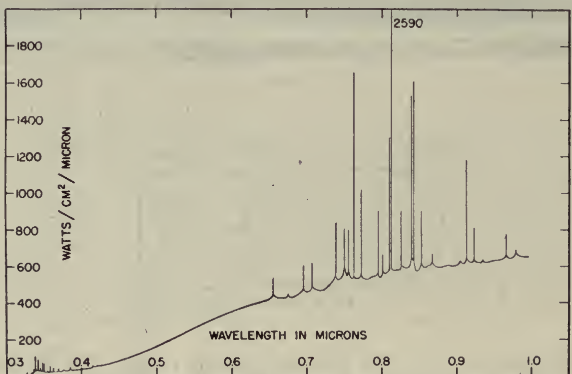


FIG. 7. Spectral distribution of radiation from a 100-w concentrated-arc lamp.

Fig. 4 shows a sectional view of a cathode which has reached the end of its useful life because of loss of material. The difficulty lies in starting the lamp. Because of the shielding effect of the protruding side walls, it is difficult to get the arc to strike to the zirconium surface, it being more apt to strike to the side wall itself. If the arc does strike to the zirconium surface, the lamp will operate satisfactorily until it is turned off, then the same difficulty will be experienced when it is turned on again. Warning that the end of the life of the lamp is approaching is given by difficult starting.

An important characteristic of the lamps is shown by Fig. 5. Here it is seen that the spatial distribution of light from concentrated-arcs follows Lambert's law and has a cosine distribution. That is, the

light emitted in a given direction may be calculated by multiplying the maximum candlepower by the cosine of the angle between the axis of the cathode and the direction considered.

If a 100-w concentrated-arc lamp and a 100-w tungsten filament lamp are measured with a foot-candle meter, it will be found that the readings are nearly equal. Thus on a candlepower output per watt input basis, they are similar. It must be pointed out, however, that the light from the tungsten filament lamp is emitted in all directions, as is shown in the drawing, while that from the concentrated-arc is but in one general direction. When these volumes are integrated to obtain the total light or lumen output of the lamps, it is found that the concentrated-arc lamp has but one-fourth as many lumens as a

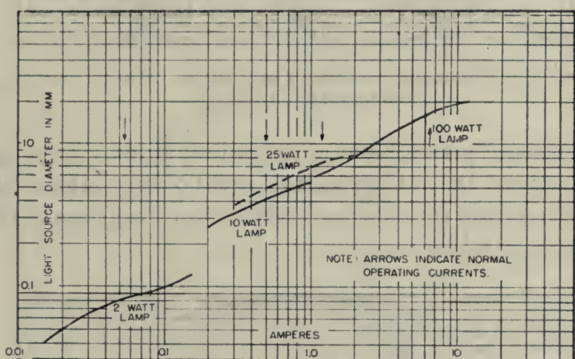


FIG. 8. Change of light source diameter with current of concentrated-arc lamp.

tungsten filament lamp of equal candlepower. It is for this reason that concentrated-arc lamps are not recommended for general illumination applications such as room lighting or flood lighting, but rather for those uses where its small size or high brightness are of major importance.

The cathode-current densities in the concentrated-arc lamp vary from about 250 amp per sq cm for the 100-w lamp to about 900 amp per sq cm for the 2-w lamp. Assuming the electron emitter to be the thin zirconium layer at a temperature slightly below 3000 K, the melting point of the oxide and using the constants commonly given for a zirconium filament in a vacuum, values of electron emission are obtained which are of the order of 500 amp per sq cm. This value is entirely in line with the actual current densities found in the lamps

and seems to confirm the present belief that the arc is maintained largely by thermionic emission, and that the active surface of the

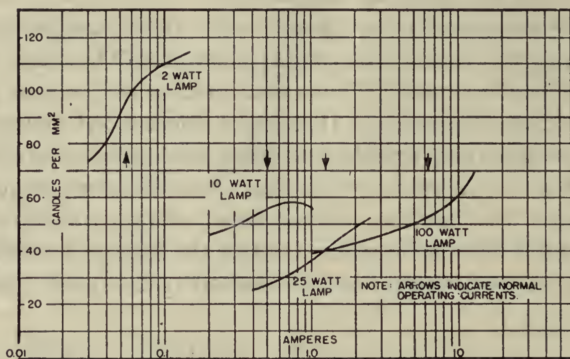


FIG. 9. Change of maximum brightness with current of concentrated-arc lamp.

cathode consists of a thin layer of zirconium atoms at a temperature considerably above the normal melting point of the bulk metal.

The radiation from the concentrated-arc lamp appears to be divided into three parts as follows:

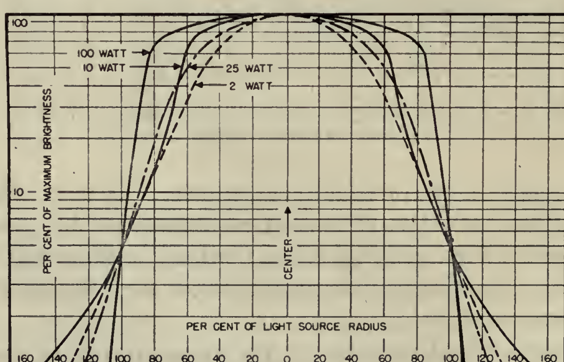


FIG. 10. Average cathode brightness distribution of concentrated-arc lamps.

(*1*) Continuous radiation from the molten cathode surface,

(*2*) Line radiation from the excited gas and vapor,

(*3*) Continuous radiation in the spectral region from at least 3500 A to 5000 A originating in the excited gas and vapor.

The existence of the three types of radiation is shown by the spectrograms in Fig. 6. The three exposures were made from the cathode

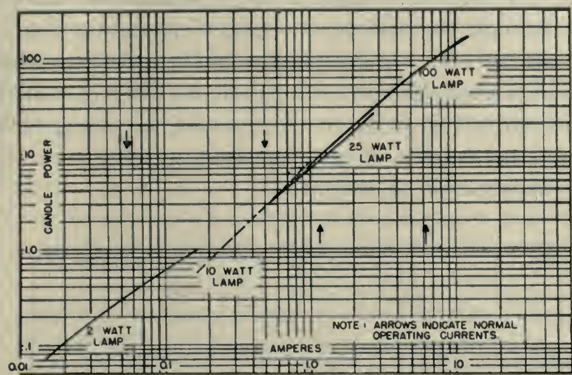


FIG. 11. Change of candlepower with current of concentrated-arc lamps.

spot, cathode glow, and anode glow portions of the arc of a specially constructed 100-w lamp. The cathode spot is by far the brightest portion. Even though the exposure time for the three traces varied in the ratio of 1:10:100, it is found that the trace of the cathode spot

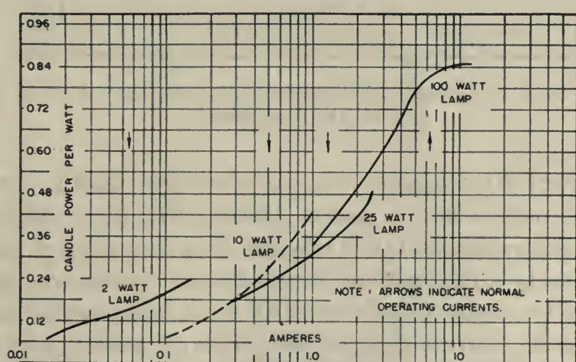


FIG. 12. Change of efficiency with current of concentrated-arc lamps.

area is more than 10 times as intense as that of the cathode glow area.

Thus concentrated-arc lamps emit radiation from two main sources, the white-hot zirconium cathode surface and the cloud of excited zirconium vapor and argon gas in the cathode glow region which extends

for a few thousandths of an inch from the cathode. The portion which originates from the cathode surface has a continuous spectral distribution. It extends in measurable amounts from 2500 A in the ultraviolet, through the visible, reaching a maximum near 10,000 A and on into the infrared. That portion of the radiation which comes from the cloud of excited vapor and gas shows three principal spectra, a continuum extending from the ultraviolet to about 5000 A, the normal, singly, and doubly ionized zirconium spectrum and the normal and singly ionized argon spectrum.

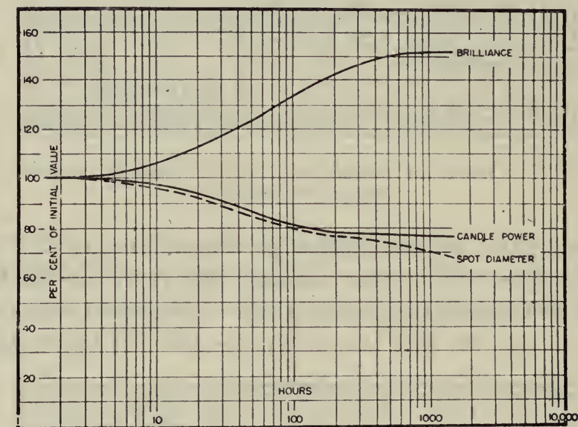


Fig. 13. Change of characteristics with age of 10-w concentrated-arc lamps.

The spectral distribution characteristic shown in Fig. 7, thus represents the combination or sum of these several individual spectra. Radiation shorter than 3000 A or longer than 5 microns is not transmitted by the type of glass used for the bulbs of standard-type lamps.

The diameter of the cathode spot of a given lamp depends upon the current. If the current is increased, the spot slowly grows larger, taking several seconds to adjust itself to the new condition. Fig. 8 shows how the diameter of the light sources vary from 0.05 mm to 3.5 mm as the lamp currents are changed in the several standard sizes of lamps. While the lamps are designed to operate at a definite current value, it is possible to adjust the spot size by changing the current.

One of the advantages of the concentrated-arc is its high brightness. As shown by Fig. 9, the maximum brightness of standard lamps at their

normal operating current varies between 40 and 100 candles per sq mm.

To the eye, the cathode spot appears to have a uniform and constant brilliance. Measurements show that the brightest part is near the center. The average brightness variation across the spot, for the several sizes of lamps, is shown in Fig. 10.

The candlepower increases with the current, maintaining an almost linear relationship over a very wide range as shown by the curves of Fig. 11.

The efficiency of concentrated-arc lamps, as measured in candlepower per watt input to the lamp, varies between 0.15 for the 2-w lamp to 0.8 for the 100-w lamp. This characteristic is shown in Fig.

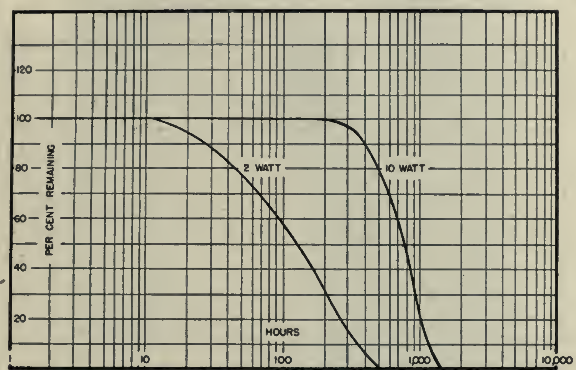


FIG. 14. Mortality curves for 2- and 10-w concentrated-arc lamps.

12. Comparable figures for tungsten filament lamps range from 0.54 for a 6-w lamp to 1.29 for 100-w lamps.

The average changes in the major characteristics of 10-w lamps during aging are shown by the curves of Fig. 13. These show that during the first few hours of running, the candlepower and light spot diameter will decrease, while the maximum brilliance increases. After about 100 hr of operation, these characteristics become reasonably stable.

The mortality curve of Fig. 14 shows the average life of 2-w lamps to be 175 hr. Similar data on larger lamps give 700, 800, and 1000 hr on 10-, 25-, and 100-w lamps although individual lamps have shown lives up to 5000 hr. Failure is usually caused by loss or shrinkage of the cathode filling material.

Concentrated-arc lamps have a negative volt-ampere characteristic as is shown by the curves of Fig. 15. Consideration must be given this fact in the design of their power supplies which will be considered a little later in this paper.

While it is impossible to predict more than a few of the many specific uses which will be found for these new lamps, it is thought that many of them can be put into three general classifications. The first is the use of concentrated-arcs as point sources. Of course, there is no such thing as a true point source, for if it has no area it must of necessity be infinitely bright. The smaller sizes of concentrated-arcs are a close approach, however, to point sources and many interesting and useful things can be done with them.

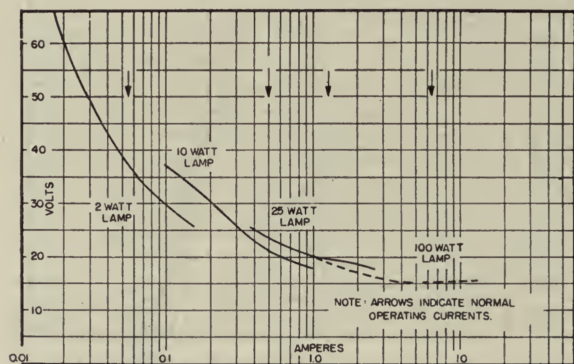


Fig. 15. Volt-ampere characteristics of concentrated-arc lamps.

Since the light rays radiate from what is almost a single point, the lamps can be used to throw very sharp shadows and used as lensless enlargers as shown by the shadow of the child's mitten in Fig. 16. The lamp and mitten can be seen in the lower corner of the picture. The shadow is projected on the wall with considerable enlargment, but even so, the shadows of the fuzz of the yarn stand out clearly. It will be noted that each tiny strand is outlined with a diffraction pattern.

A small concentrated-arc makes an excellent source with which to test lenses, adjust optical devices, and demonstrate lens aberrations and other optical phenomena. Fig. 17 shows the caustics produced when point source lamps are placed slightly off the axis and inside the

principal focus of two short focus plano-convex condensing lenses. A lens designer would need a little time to calculate this figure. Many interesting and instructive demonstrations and tests can be made with these brilliant point sources.

A second general field of application of concentrated-arc lamps is their use in conjunction with lenses. Fig. 18 shows a point source at the principal focus of a condensing lens. Since the source is so small,

FIG. 16.

the rays leaving the lens are almost exactly parallel. Such an arrangement makes an unusual contact printer for photography in which close contact between the negative and print are not necessary.

A use of point source lamps which has even wider application is shown in Fig. 19. This is the case where the point source is used as the source of illumination in optical systems. The particular system pictured is supposed to represent a photographic enlarger. Since the source is a point, the rays leaving the condenser are substantially parallel. Thus, the ray passing through point A on the negative or film goes on to strike the enlarging lens at only point A on the lens

and passes through the lens to form the image on the screen. The same sequence is followed by the rays passing through each point of the film, the important fact being that there is but little scattering of the rays at the film so the light from each microscopically small element of the film passes through only one equally small area of the lens. Thus for each elementary area, the lens acts as if it were stopped down to an extremely small aperture, $f/200$ or less, and forms an image having the extreme sharpness and depth of focus which corresponds to such an aperture, but there is not the corresponding loss of light, for the whole lens is working. This explains why it is that,

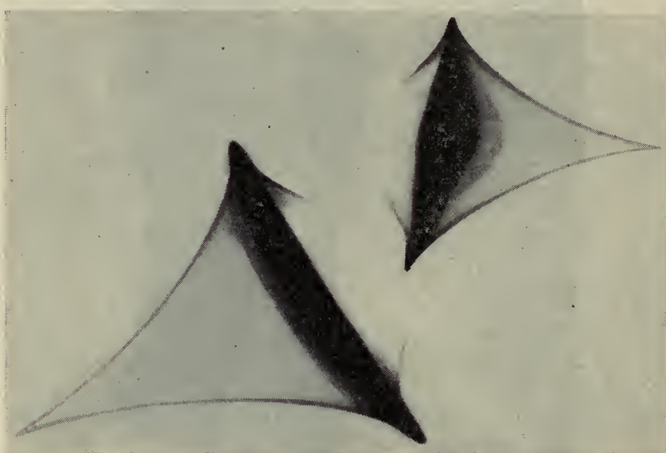


FIG. 17.

when point source lamps are used with optical devices, images are formed which have unusual definition and depth of focus.

In actual applications, the system might appear as shown in Fig. 20. Here the point source is so positioned in respect to the condensing lens that the rays converge in leaving the condenser. This arrangement results in exactly the same stopping effect as before and has the advantage that the enlarging lens need not be as large as the negative.

Fig. 21 shows the extreme depth of focus of the image projected with a photographic enlarger equipped with a point source lamp as compared to that obtained when the same enlarger uses a large source

tungsten filament lamp. This group of pictures shows that when the enlarger is focused for a 36-in. projection distance, a fairly well focused image is found at a 27-in. projection distance when using the point source. When a large source lamp is used in the same enlarger, the image is very poor at this 27-in. position.

The design of a practical lens usually involves a series of compromises. One error cannot be fully corrected without causing some other to increase to serious magnitudes. Since many of the common lens aberrations decrease as the lens is stopped down, and since using a point source lamp with lenses produces a stopping effect, it may be that a lens could be designed particularly for use with point sources and produce results far superior to those produced by any lens now available.

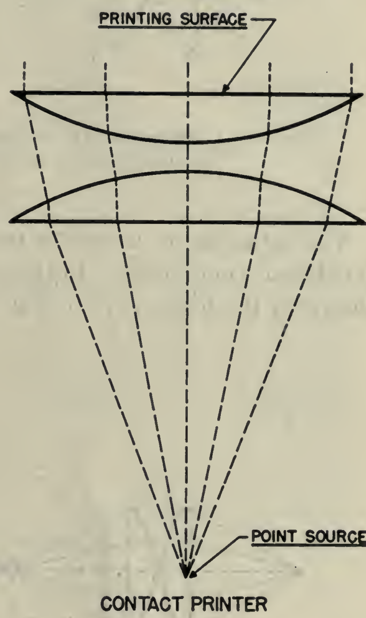


FIG. 18. Contact printer.

The increased sharpness and depth of focus which result from the use of point source lamps in photographic enlargers are also secured in many other optical devices when point source lamps are substituted for the large lamps normally employed. In microscopy the results are quite marked as shown by the photomicrographs of Fig. 22.

The third general field of application of concentrated-arc lamps is in projection. Fig. 23 diagrams a simple projector system. The problem in many such systems is to get the maximum amount of light from the source through a small opening such as the film gate and on through the projection lens to the screen. Optically, the way to get maximum light through a small opening is to image the source at the opening or film gate. The upper view of Fig. 23 shows a projector using a concentrated-arc lamp source adjusted to this condition. Since the concentrated-arc has a uniformly brilliant disk of light, its

image when placed at the film gate results in a uniformly illuminated screen.

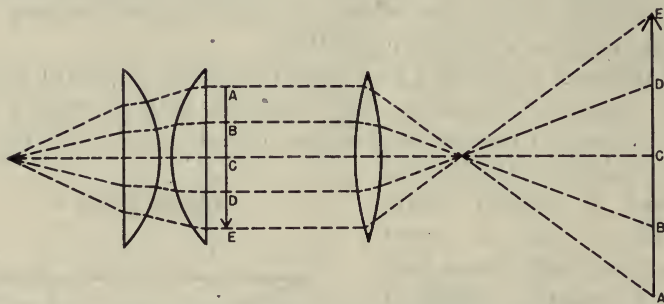


FIG. 19. Diagrammatic representation of a hypothetical photographic enlarger with point source illumination.

This adjustment cannot be used when a tungsten filament projection lamp is employed. In this case, the projector must be set up, as shown in the lower part of Fig. 23, so the coils of hot tungsten are

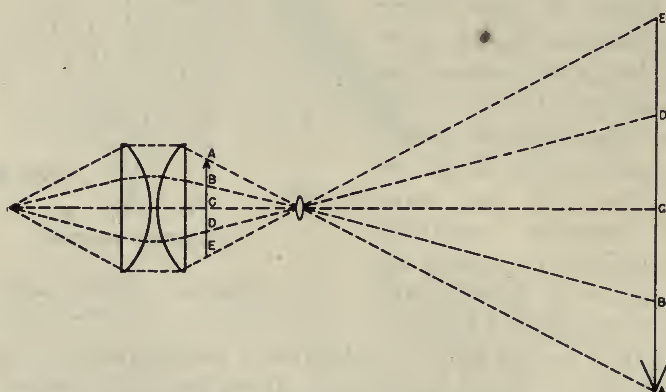


FIG. 20. Diagrammatic representation of a conventional photographic enlarger with point source illumination.

imaged not at the film gate but in front of the projection lens. If they were imaged at the film gate, the image of the hot coils would appear on the screen. Since so much light is lost at the gate under the adjustments necessary with tungsten filament lamps, the effi-

ciency of transferring light to the screen is low. Concentrated-arc lamps can thus be used much more efficiently in such projector systems.

A second factor in favor of the concentrated-arc in projection systems of this type is that the screen brightness is a direct function of the source brightness. Since the new lamps are brighter than tungsten filament lamps, they also show an advantage from this standpoint.

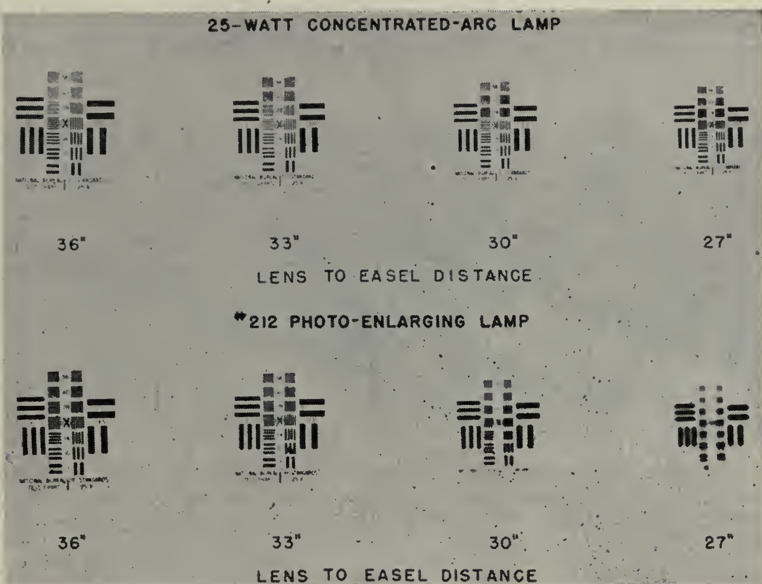


FIG. 21. Enlargements illustrating depth of focus with $f/4.5$, 2-in. lens focused for 15× magnification.

As a practical result of these advantages, it was found in a recent test that a 100-w concentrated-arc lamp would put more lumens on the screen through an 8-mm film projector than could be obtained when a 500-w tungsten filament type projection lamp was used.

The largest size of concentrated-arc now in production is the 100-w lamp. This lamp has a source 0.060 in. in diameter. Using a good condenser system, it is possible to magnify this small spot to cover the film gate of an 8-mm film projector.

An experimental concentrated-arc lamp which has a source spot diameter of $^3/_{16}$ in. and operates on 450 w has been made for 16-mm

projectors. Fig. 24 shows an experimental 1500-w concentrated-arc lamp which, with its 4000 cp coming from a spot 3/8 in. in diameter, seems to be adapted for use in 35-mm film projectors.

There are probably many uses which will be found for the new concentrated-arc lamps; the few which have been discussed are intended only to show the peculiar advantages of the lamps in several general types of applications.

The usual type of concentrated-arc lamp requires a high voltage pulse to break down the gap between the anode and the cathode and to establish the arc and a supply of direct current to maintain the

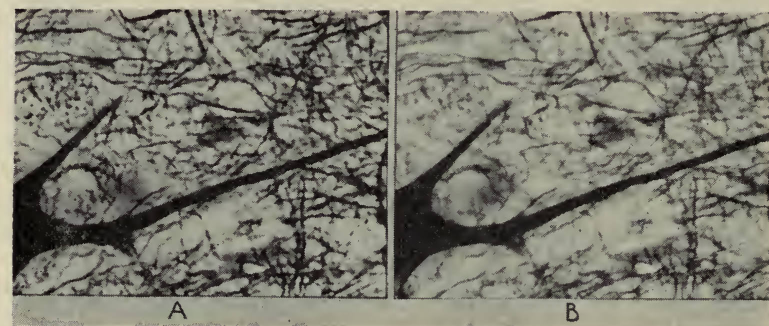


FIG. 22. Photomicrographs illustrating the increased detail rendition and depth of field made possible by the concentrated-arc in *A* as compared with conventional illumination in *B*.

arc. In the laboratory, this is easily accomplished with the simple circuit shown in Fig. 25. Here the lamp is connected through a resistance and radio frequency choke coil to the 110-v, d-c supply line taking care to connect the lamp with correct polarity. When a hand held spark coil, sometimes known as a Tesla coil, vacuum leak tester or violet ray coil, is touched to the lamp lead, the high-frequency spark jumps the gap in the lamp and the arc is established on the direct current from the line. This circuit is suitable for 10-, 25-, and 100-w lamps. Two-watt lamps can be operated in a like manner if the supply main has a potential of 200 v or over. In every case, the series resistance must be adjusted to limit the current through the lamps to the value recommended for the particular size of lamp used.

A convenient power supply for a 2-w lamp is shown in Fig. 26. This operates from 110 v, a-c and with a simple voltage doubler rec-

tifier delivers 220 v, d-c to the lamp. The high starting voltage is secured with the aid of the series choke coil and a momentary contact switch which is connected across the lamp terminals. When this switch is operated, the inductive pulse generated by the choke coil is sufficient to start the lamp.

Fig. 27 pictures a group of power supplies which operate from 110 v, a-c and supply the necessary high voltage starting and direct-current

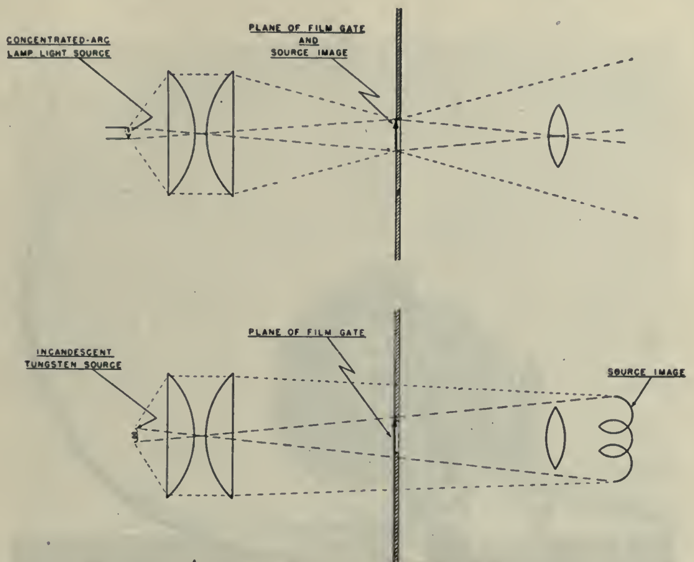


FIG. 23. Projection systems with concentrated-arc lamp (top) and with tungsten filament lamp (bottom).

running power for the various size lamps. The general type of circuit used is shown in Fig. 28. This circuit combines two rectifiers, a high voltage transformer and vacuum tube rectifier for the starting potential and a low voltage transformer and selenium rectifier for the running current. A relay automatically switches the lamp from one to the other as soon as the arc strikes. This type of power supply is very satisfactory from an operating standpoint, but is heavy, bulky and comparatively expensive.

An alternating-current type of concentrated-arc lamp is being developed to avoid these difficulties. The direct-current type lamp

consists of the cathode and a single anode. The alternating-current type has two anodes which, when properly connected to a center tapped transformer, allow the lamp to rectify within itself the current flowing through the cathode. Incidentally, the lamps make such good rectifiers that they may eventually find their major use in this field, rather than that of illumination. The necessity of a high voltage for starting is avoided in the alternating-current type lamp by the use of an auxiliary tungsten filament which is built into the lamp

FIG. 24. An experimental 1500-w concentrated-arc lamp.

This filament is heated for an instant during the starting sequence and provides the ionization necessary to establish the arc, the whole process requiring but a fraction of a second.

The appearance of the power supply for the new 100-w, a-c type concentrated-arc lamp is shown in Fig. 29. As compared to the power supply for the direct-current type lamp, the new supply has the advantage of less than one-half the weight, one-third the bulk, and one-quarter the cost. The circuit diagram of the supply for the alternating-current lamp is shown in Fig. 30. The comparative simplicity of this new power supply is apparent.

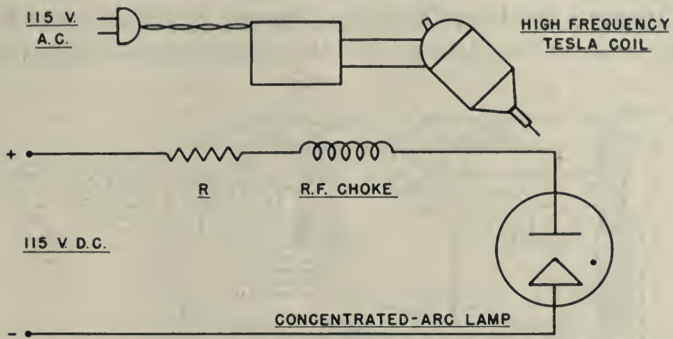


FIG. 25. A circuit for running lamps from direct-current mains. The tesla coil and RF choke are included for starting purposes.

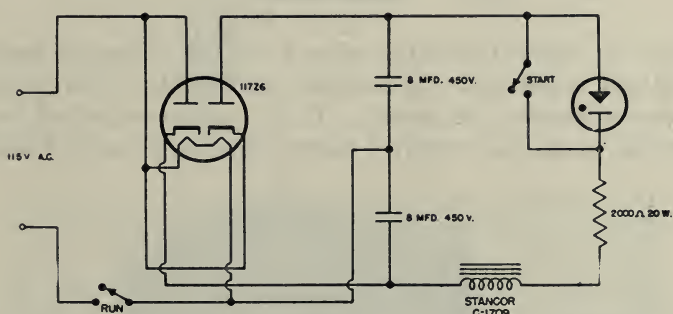


FIG. 26. Schematic diagram of a power supply for 2-w concentrated-arc lamps.

FIG. 27. Concentrated-arc lamp power supplies.

In starting this lamp, first, the filament is lighted, then the arc strikes between the filament and the cathode, heating the cathode.

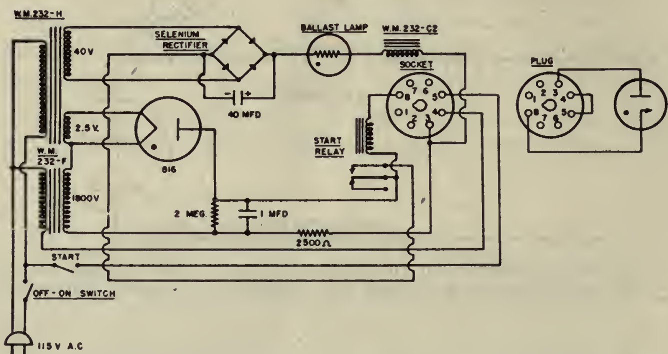


Fig. 28. Schematic diagram of a 25-w concentrated-arc lamp power supply.

Finally, the filament is turned off and the thin zirconium surface of the cathode is maintained in a molten condition by the arcs from the two anodes working alternately. If the lamp is turned off for only an instant, it may be restarted without the use of the hot filament.

Fig. 29. A power supply for a 100-w, a-c type concentrated-arc lamp.

If the interruption is long enough to allow the cathode to cool too much, the lamp will not restart without the aid of the heated filament.

As the arc is turned off and on again, the boundaries of the molten pool spread out. It should also be noted that the bright zirconium

pool always remains in the same position, is sharply outlined, and appears to be uniformally bright.

The lamp can be burned in any position and moved around in any desired manner. In this respect, it is quite different from the usual tungsten filament projection lamp which must be burned in only the specified position and is very sensitive to motion and shocks.

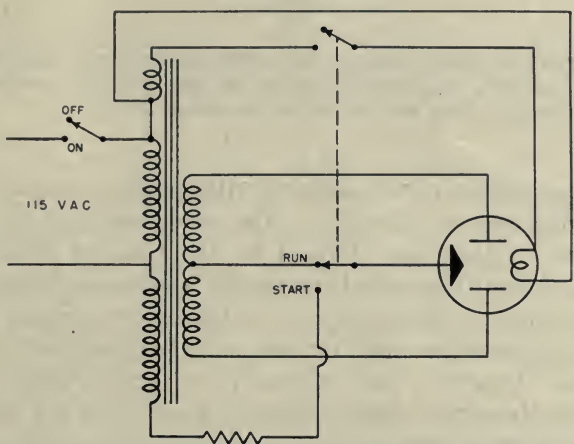


FIG. 30. Schematic diagram of a power supply for 100-w a-c type concentrated-arc lamps.

In this discussion, an attempt has been made to show what the concentrated-arc lamp is , how it works, what its characteristics are, and some of the things it can be used for. Its characteristics and properties are so different from those of any other type of lamp now available, and the results which can be obtained with it are so unique that it is hoped that concentrated-arc lamps will prove to be useful in the solution of many of the problems of science and industry.

OPTICAL PROBLEMS OF THE IMAGE FORMATION IN HIGH-SPEED MOTION PICTURE CAMERAS*

JOHN KUDAR**

Summary.—*The optical design of high-speed cameras can be improved by considering the results of a systematic analysis of the various optical aberrations which arise with the rotation of the polygonal refracting prism.*

High-speed motion picture cameras with rotating polygonal prisms have recently been described.[1,2] The nonlinearity of the parallel displacement of the image formed by the rotating prism (plane-parallel plate) results in optical aberrations which must be kept within reasonable limits.[3] This is achieved in high-speed cameras by using a rotating shutter represented by dark parts between the consecutive prism faces. However, the rotating plane-parallel plate produces several other aberrations which, although less obvious but much more intricate than the nonlinearity of the parallel displacement of a ray, must nevertheless be considered in the optical design of high-speed cameras.

The optical aberrations produced by the rotating plane-parallel plate can be classified as analogies to the well-known lens aberrations as follows.

Lens calculations based upon the approximation that $\sin x = x - x^3/6$ give account of spherical aberration, coma, curvature of field, astigmatism, and distortion. The camera lens and the polygonal prism behind it, in the position in which the optical axis of the lens is perpendicular to two parallel faces of the polygonal prism, can be designed of course as a well-corrected lens system. Then the rotation of the prism produces periodic aberrations, which have no axial symmetry and are to be related to the tangential and sagittal sections of the rotating prism. These prismatic aberrations are analogous to the five lens aberrations. For instance, the nonlinearity of the parallel

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** London, England.

displacement of a ray is an effect corresponding to distortion in lens optics.

There is a prismatic astigmatism, too; the field curvature of lens optics corresponds here to the varying positions of the astigmatic image planes. Finally, the periodically varying prismatic coma is also a very interesting aberration of great practical importance. The analogy between these periodic aberrations caused by the rotating prism and the axially symmetrical aberrations of lens optics becomes immediately obvious by considering the variation of the former during the rotation of the prism. Thus the axially symmetrical aberrations caused by the prism, when its two faces are just perpendicular to the optical axis, will change continuously to the tangential and sagittal prismatic aberrations. However, the spherical aberration of the prism is independent of the rotation. It is sufficient, therefore, as far as spherical aberration is concerned, to achieve the optical correction for the camera lens and the prism together.

It is of practical importance to compare the numerical values of the varying prismatic aberrations. This task involves detailed optical calculations[4] the results of which regarding high-speed cameras can be summarized as follows.

Let D represent the distance between parallel faces of the rotating prism, n the refractive index of the prism, x the angle of incidence of the principal ray belonging to any image point, τ and σ the half angular aperture of the rays participating in the formation of any image point in tangential and sagittal prismatic sections.

The prismatic coma is an aberration perpendicular to the direction of the principal ray and to the prism axis. The numerical value of the tangential coma is

$$\left(D\cdot\frac{n-1}{n}\right)\frac{3}{2}\cdot\frac{n+1}{n^2}\cdot x\cdot\tau^2 \qquad (1)$$

and the sagittal coma:

$$\left(D\cdot\frac{n-1}{n}\right)\cdot\frac{1}{2}\cdot\frac{n+1}{n^2}\cdot x\cdot\sigma^2. \qquad (2)$$

The tangential and the sagittal image planes vary continuously their positions along the principal ray during the rotation of the prism and the distance between them is the numerical value of the prismatic astigmatism:

$$\left(D\cdot\frac{n-1}{n}\right)\cdot\frac{n+1}{n^2}\cdot x^2. \qquad (3)$$

The nonlinear term in the parallel displacement of the principal ray is

$$\left(D\cdot\frac{n-1}{n}\right)\left(\frac{n+1}{2n^2}-\frac{1}{6}\right)\cdot x^3. \qquad (4)$$

One can easily obtain approximate information about the average values of these aberrations in considering principal rays parallel to the axis of the lens system. Thus the angle of incidence x equals the angle of rotation of the prism starting from the position in which its faces are perpendicular to the axis of the lens system.

Comparing Eqs (*1*), (*2*), (*3*) with (*4*) in practical cases in which the maximum angle of rotation of the prism[2] may be $x = 1/5$ ($= 11^1/_2$ deg.) and an aperture $f/2$ might be used,[1] prismatic coma and astigmatism result in much greater aberrations than the nonlinearity (*4*) could ever produce. Thus the correction of the latter by suitable dimensioning of D does not mean necessarily that the image formation will be of perfect quality regarding the other aberrations.

Careful consideration of these results in the optical design of high-speed cameras could open the possibility for improvements which may be of practical importance.

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AN IMPROVED METHOD FOR THE DETERMINATION OF HYDROQUINONE AND METOL IN PHOTOGRAPHIC DEVELOPERS*

H. L. BAUMBACH**

Summary.—*A new method for the quantitative chemical analysis of hydroquinone and metol is suggested that is more rapid and, in some cases, more accurate than previous methods.*

Molecular hydroquinone and methyl p-*amino phenol are extracted from the developer at* p*H 8.0 to 8.5 with methyl acetate. The extract is dissolved directly in water and titrated with hydrochloric acid to determine metol, and then with iodine at* p*H 6.5 to 7.0 to determine the sum of the metol and the hydroquinone.*

Introduction.—Accurate chemical analyses of photographic developing solutions are a very necessary part of the chemical control of continuously replenished developers. The analytical determinations of bromide and sulfite and the measurement of *p*H are practically as rapid and accurate as could be desired. The determination of hydroquinone and metol, however, has been time consuming and, in some cases, not sufficiently accurate. For example, many negative solutions utilize a low concentration of metol in the presence of a high concentration of hydroquinone. At the *p*H values at which such developers operate, metol is practically the only effective developing agent, and its low concentration needs to be determined accurately, often to ±0.01 gram per liter.

Present methods of analysis for hydroquinone and metol are usually based upon an extraction of the hydroquinone alone from the acidified developer, using an immiscible organic solvent, such as ethyl ether, and a second extraction of hydroquinone and metol base from another sample of developer, which, in this case, has been adjusted to a *p*H of about 8.5. The metol concentration is thus determined by difference. Extraction of the hydroquinone from the developer sample at a *p*H of about three and subsequent extraction of the same sample for

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* Presented May 6, 1946, at the Technical Conference in New York.

** West Coast Laboratory, Paramount Pictures, Inc., Hollywood.

metol at *p*H 8.5 is not always practical, since metol base is easily oxidized by the air, in the absence of hydroquinone.

The methods of Lehmann and Tausch,[1] Evans and Hanson,[2] Baumbach,[3] Atkinson and Shaner,[4] Evans, Hanson and Glasoe,[5] and Stott[6] have all been based upon this idea of two separate extracts at two *p*H values.

In an effort to shorten the analytical methods and to obtain more accuracy in the determination of metol, research performed in this laboratory has resulted in a new procedure which permits hydroquinone and metol base to be determined in a single extract. A new solvent has been selected which has the property of being only slightly soluble in a salted developer and yet very soluble in pure water, thereby eliminating the need for evaporating the extracting solvent in order to obtain the hydroquinone and the metol base in a form suitable for analysis. This solvent also possesses a high extraction coefficient for both hydroquinone and metol base, being superior to ethyl ether in this respect.

Selection of a Suitable Solvent.—In the course of the testing of a number of solvents that might be used to extract hydroquinone and metol base from developing solutions, one solvent was found that possessed the desired properties to a high degree. Methyl acetate has the ability to extract 70 per cent of the hydroquinone and 80 per cent of the metol from an equal initial volume of typical developing solution at a *p*H of 8.5 and at a temperature of 70 F. When the developer is saturated with potassium bromide, over 90 per cent of both agents is extracted by an equal initial volume of the solvent. Two such extractions result in less than one per cent of each agent remaining in the developer. Methyl acetate does not extract developing agent oxidation products (sulfonates) from a developer containing sulfite nor at this *p*H is there any sulfur dioxide extracted.

There are several advantages to the use of methyl acetate in place of ethyl ether. Methyl acetate is a somewhat safer solvent to use, since its flash point is 20 F and its lower explosive limit is 4.1 per cent by volume in air, while the flash point of ethyl ether is -20 F with a lower explosive limit of 1.7 per cent. The lower vapor pressure of methyl acetate likewise makes this solvent superior to the use of ethyl ether. The solubility of methyl acetate in water is considerable, being 32 grams per 100 ml of water at room temperature. This solubility enables the extract to be dissolved directly in water for analysis and obviates the need for solvent evaporation.

The Determination of Hydroquinone and Metol in a Common Solution.—Methyl *p*-amino phenol is amphoteric; it can act either as an acid or a base. On the other hand, hydroquinone possesses only hydroxyl groups and can function only as an acid. Therefore, metol base can be determined in the presence of a large excess of hydroquinone by titrating the mixture with strong acid. Fig. 1 shows the relationship between *p*H and the volume of standard hydrochloric acid during the course of the titration of a dilute solution of metol base.

Since the basic properties of metol are so mild, the use of a color indicator in such a titration will not yield results of sufficient accuracy for most purposes. The end-point can be determined accurately, however, by the usual potentiometric procedure, the continuous reading *p*H meters being very satisfactory for this purpose. Unfortunately, a pure water solution of metol base permits the latter quickly to be oxidized by the dissolved oxygen, unless precautions are taken to provide an inert atmosphere. This is especially true at *p*H values above six. The rate of oxidation can be greatly reduced, however, by reducing the polarity of the solvent. Thus metol base is relatively stable in a solvent mixture of 75 per cent water and 25 per cent isopropyl alcohol, or in the same percentages of water and methyl acetate. Decreasing the polarity of the solvent also decreases the sharpness of the inflection for the acid titration, as is shown in Fig. 2, but the titration is still a practical one. The *p*H at which the inflection occurs is a function of the concentration of the metol base; therefore, it is necessary to plot a titration curve for an unknown developing solution. For control purposes, where the concentration of metol in a developer will not vary greatly, it is practical to titrate the extract with acid to a given *p*H. Fig. 2 shows the *p*H values of the inflections for developer concentrations of metol, if the procedure that is described below is followed.

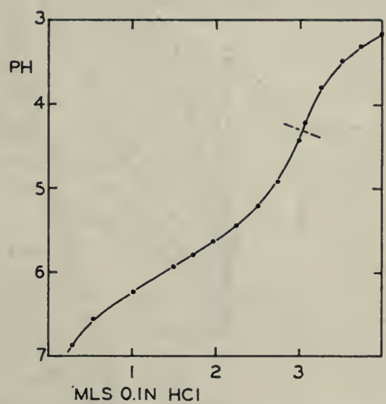

FIG. 1. Titration with hydrochloric acid of metol base in water solution.

After the titration of the metol base with acid, the same solution may be titrated with standard iodine solution. Iodine oxidizes hydroquinone and metol base quantitatively to quinone and methyl quinone imide, respectively, if the resulting hydriodic acid is neutralized with alkali as the reaction progresses. At *p*H values much below seven, the reaction does not go to completion and at *p*H values in excess of eight, the reactions between oxygen and the reducing agents are rapid enough to cause errors.

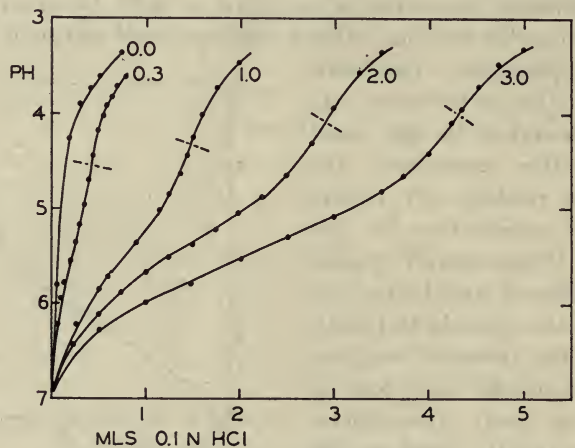

Fig. 2. Titrations with hydrochloric acid of metol base in a solution of 25 per cent methyl acetate and 75 per cent water. Numerals refer to concentrations of metol in the original developer samples.

Procedure.—Pipette 25.0 ml of the developer sample into a 250-ml separatory funnel. Add 0.5 ml of thymol blue indicator solution and neutralize the alkali of the developer with concentrated hydrochloric acid until the blue color just changes to yellow, or adjust the *p*H of the developer sample between 8.0 and 8.5 by any other means.

Add 15 grams of fine, granular potassium bromide and 25 ml of methyl acetate. Shake the funnel vigorously for 3 min and allow the layers to separate for 3 min. Drain the water into a clean beaker and pour the organic layer into a clean, dry 100-ml beaker. Return the water layer to the separatory funnel and rinse the beaker with 25 ml more methyl acetate, which should be added to the funnel.

Repeat the shaking and the separation, using the second methyl acetate extract to rinse the surfaces that held the first.

Pour the extract of the first separation successively through two additional dry 100-ml beakers, in order to make the removal of water complete, and finally place the extract into a 400-ml beaker. After the second extract has followed the first, add 150 ml of distilled water and mount the beaker into a titration unit that provides the calomel and glass electrodes, burettes for the hydrochloric acid and the iodine, and a motor stirrer.

Titrate the solution containing methyl acetate, hydroquinone and metol base with 0.0500 N hydrochloric acid, plotting a titration curve of pH versus volume of reagent or, in routine work, titrate to the specific pH corresponding to the point of inflection.

Add an additional 150 ml of water with 10 ml of starch indicator and titrate with 0.100 N iodine solution. During the titration, add sufficient 10 per cent disodium phosphate solution to maintain a pH between 6.5 and 7.0. The end-point is taken when a stable bluish color is produced.

CALCULATIONS

ml of 0.0500 N HCl $\times$ 0.344 = grams per liter of metol in developer.

(ml of 0.100 N KI_3 − ml of 0.0500 N HCl) $\times$ 0.220 = grams per liter of hydroquinone in developer.

NOTES

(*1*) Some samples of methyl acetate contain sufficient methyl alcohol to make the mixture completely miscible with water. Such material is not suitable for this analysis. If approximately two-thirds of the methyl acetate remains undissolved after shaking with an equal volume of water, the material is satisfactory.

(*2*) Potassium bromide is used to "salt out" the developing agents because this salt raises the density of the water layer to a degree that permits rapid separation of the two phases after they have been intimately mixed.

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APPLICATION OF METHYL ETHYL KETONE TO THE ANALYSIS OF DEVELOPERS FOR ELON AND HYDROQUINONE*

VAUGHN C. SHANER** and MARY R. SPARKS**

Summary.—*A method of analysis for Elon and hydroquinone in developers is described involving the use of methyl ethyl ketone as the extracting solvent. Tests showed it to be a better extracting solvent for Elon and hydroquinone than methyl acetate or ethyl acetate. Analyses made employing methyl ethyl ketone with the U-tube extraction method showed it to have the necessary accuracy and reproducibility for use in production control.*

During the past few years, photographic processing control has become increasingly important. Many processing laboratories employ chemists for the express purpose of analyzing their developers daily in order that the exact chemical concentrations of the constituents may be known at all times. For this reason there has been a constant search for ways to improve the existing methods of developer analysis and many articles have been published describing various ways of determining the concentrations of developing agents. Evans and Hanson[1] published a colorimetric method, and Baumbach[2] revealed a volumetric method of determination for Elon and hydroquinone. Atkinson and Shaner[3] used a volumetric method involving extraction of Elon and hydroquinone in a *U*-tube; Stott[4] described a potentiometric method; Evans, Hanson, and Glasoe[5] employed a polarographic method for determination of Elon and hydroquinone. Recently, Baumbach has described a method of developing agent analysis involving the extraction of Elon and hydroquinone with methyl acetate. In his method, concentrations of Elon and hydroquinone are determined in the same solution by acid titration of Elon, using a *p*H meter with a glass electrode as the end-point indicator and then an iodine titration of both Elon and hydroquinone. This method is satisfactory from the standpoint of convenience and accuracy but

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** Motion Picture Film Dept., Eastman Kodak Company, Hollywood.

difficulty was encountered in obtaining methyl acetate of sufficient purity for the analysis. For this reason, the authors set out to find a new extracting solvent for Elon and hydroquinone.

Procedure.—In the analytical procedure described by Baumbach, a 25-ml sample of developer is pipetted into a 250-ml separatory funnel. Add 0.5 ml of thymol blue indicator solution and sulfuric acid until the color just turns yellow. Add 15 grams of potassium bromide. This is necessary because methyl acetate is

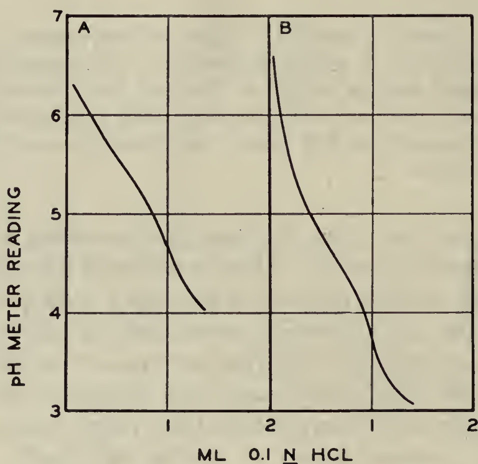

FIG. 1. Elon titration curves, model *G* Beckman *p*H meter, model *015* glass electrode —(*A*) 50 ml methyl ethyl ketone extract 200 ml water; (*B*) 50 ml methyl ethyl ketone extract 10 ml methanol 10 ml water.

quite soluble in water which is not saturated with salt. Add 25 ml of methyl acetate and shake 3 min. Let stand 3 min, and separate into three dry 100-ml beakers in series. Repeat the extraction step with an added 25-ml portion of methyl acetate, and combine the two extracts in a 400-ml beaker. Add 150 ml of distilled water. Titrate the Elon base with 0.1 N hydrochloric acid, using a glass electrode as the end-point indicator. Plot the titration curve of *p*H versus milliliters of hydrochloric acid. Add 150 ml of distilled water, and fresh starch solution. Titrate slowly with 0.1 N iodine, after the *p*H is raised to a value of 7.0 by the addition of a buffer, such as disodium phosphate. Compute the hydroquinone concentration by the differ-

ence between the Elon titration and the total as determined by the iodine titration.

In this laboratory it was found more convenient to employ a *U*-tube extractor of the type used by Atkinson and Shaner rather than a separatory funnel. It was deemed desirable, therefore, to adapt Baumbach's procedure to this *U*-tube extractor. A developer sample volume of 10 ml has been found about the largest practical to use with a *U*-tube extractor. However, it was discovered that the large water dilution of the methyl acetate extract prior to the Elon titration led to a curve, the end-point of which was hard to determine. Preliminary tests showed that this large dilution could be avoided by the use of 10 ml of methyl alcohol and 10 ml of water to make the solution sufficiently polar for the titration. In Fig. 1 are reproduced titration curves which show the comparison of titrations carried out with and without methyl alcohol. Curve *A* was obtained from the titration of solvent extract with a large dilution of water, while curve *B* was obtained from the titration of solvent extract with only 10 ml of water and 10 ml of methyl alcohol. By reference to the figure it may be seen that curve *B* has a precise inflection point, making it possible to read the end-point of the titration more easily. Accordingly, an experimental procedure was set up to include these modifications.

Pipet a 10-ml sample of developer into the funnel attached to a *U*-tube extractor. Add 5 drops of 0.04 per cent thymol blue indicator dye and one to one sulfuric acid until the color just turns yellow. Saturate the developer sample with potassium bromide. Run 50 ml of solvent through the extractor and collect at the delivery end of the *U*-tube in a dry graduate cylinder. Pour the solvent extract into a mixture of 10 ml of distilled water and enough methanol to make the solution miscible. Titrate with 0.1 N hydrochloric acid, using a *p*H meter with a glass-calomel electrode system as an end-point indicator, and plot the titration curve. Compute the Elon concentration as follows:

$$\text{Elon in grams per liter} = \frac{(\text{ml Hcl} \times \text{N Hcl}) \times 172}{\text{ml of sample}}.$$

Add 200 ml of distilled water, starch solution and disodium phosphate crystals to bring the *p*H to 8.0 and titrate the combined Elon and hydroquinone with 0.1 N iodine. Compute the hydroquinone concentration as follows:

$$\text{Hydroquinone in grams per liter} = \left[\frac{(\text{ml } I_2 \times \text{N } I_2)}{\text{ml of sample}} - 2\,\frac{(\text{ml Hcl} \times \text{N Hcl}}{\text{ml of sample}}\right] \times 55.$$

Tests of Solvents.—The solvents selected for the tests in this work were methyl acetate, ethyl acetate, and methyl ethyl ketone. A developer with high concentrations of Elon and hydroquinone was mixed according to the following formula:

Elon	3.3 grams
Hydroquinone	9.5 grams
Sodium sulfite	40.0 grams
Sodium carbonate	20.0 grams
Potassium bromide	2.0 grams
Water to make	1 liter

Samples of this developer were extracted according to the procedure just given. The 50-ml portions of solvents were collected and analyzed in 10-ml aliquots to determine the rate of extraction of Elon and hydroquinone by each of the different solvents. In order to bring the solution to workable volume it was therefore necessary to use 50 ml of distilled water. It was necessary to use 25 ml of methanol with ethyl acetate but 10 ml of methanol was sufficient for methyl acetate and methyl ethyl ketone. The data thus collected are shown in Tables 1 and 2.

TABLE 1

Elon Found in Grams per Liter

Extraction Number	Total Volume of Solvent (in ml)	Methyl Ethyl Ketone	Ethyl Acetate	Methyl Acetate
1	10	1.84	1.29	1.70
2	20	2.96	2.03	2.52
3	30	3.15	2.58	3.07
4	40	3.28	3.05	3.25
5	50	3.28	3.19	3.25

TABLE 2

Hydroquinone Found in Grams per Liter

Extraction Number	Total Volume of Solvent (in ml)	Methyl Ethyl Ketone	Ethyl Acetate	Methyl Acetate
1	10	5.35	3.31	5.04
2	20	8.70	5.52	7.17
3	30	9.14	7.04	8.49
4	40	9.28	8.15	8.97
5	50	9.28	8.67	8.97

By referring to Table 1 it may be seen that methyl ethyl ketone extracts 1.84 grams per liter of Elon, ethyl acetate extracts 1.29 grams per liter, and methyl acetate extracts 1.70 grams per liter of Elon, in 10 ml of solvent. Similarly, in 20 ml of solvent, methyl ethyl ketone extracts 2.96 grams per liter of Elon, ethyl acetate extracts 2.03 grams per liter of Elon, and methyl acetate extracts 2.52 grams per liter of Elon. From these data, it was decided that methyl ethyl ketone is a better extracting solvent for Elon than methyl acetate or ethyl acetate. Since 50 ml of methyl ethyl ketone extracted no more Elon than 40 ml of methyl ethyl ketone, it was concluded that 50 ml of methyl ethyl ketone is a sufficiently large volume for extracting all the Elon present in a 10-ml developer sample.

From Table 2, it may be seen that, in a 10-ml volume, methyl ethyl ketone extracted 5.35 grams per liter of hydroquinone, ethyl acetate extracted 3.31 grams per liter of hydroquinone, and methyl acetate extracted 5.04 grams per liter of hydroquinone. Similarly, in a 20-ml volume, methyl ethyl ketone extracted 8.70 grams per liter of hydroquinone, ethyl acetate extracted 5.52 grams per liter of hydroquinone, and methyl acetate extracted 7.17 grams per liter of hydroquinone. From these data it was decided that methyl ethyl ketone is a better extracting solvent for hydroquinone than methyl acetate or ethyl acetate. Since 50 ml of methyl ethyl ketone extracted no more hydroquinone than 40 ml of methyl ethyl ketone, it was concluded that 50 ml of methyl ethyl ketone is a sufficiently large volume to extract all the hydroquinone present in a 10-ml sample of a practical developer with a safety factor included.

TABLE 3

Solven	Methyl Ethyl Ketone	Methyl Acetate	Ethyl Acetate
Weight of Flask and Residue	78.360	75.260	71.350
Weight of Flask	63.970	65.410	63.892
Grams of Hydroquinone	14.390	9.850	7.458

In order to compare the amounts of hydroquinone which could be dissolved in methyl acetate, ethyl acetate, and methyl ethyl ketone, 50-ml portions of each solvent were saturated with hydroquinone. The solvent was evaporated to dryness and the residual hydroquinone weighed. The data thus collected are shown in Table 3.

By inspection of Table 3 it may be seen that 50 ml of methyl ethyl ketone will dissolve 14.39 grams of hydroquinone while 50 ml of methyl acetate will dissolve 9.85 grams of hydroquinone, and 50 ml of ethyl acetate will dissolve 7.46 grams of hydroquinone. From these data it is concluded that methyl ethyl ketone is a better solvent for hydroquinone than is methyl acetate or ethyl acetate.

Of the two solvents, methyl acetate and methyl ethyl ketone, methyl ethyl ketone has the advantage that in California it is more easily obtainable in a purer form than methyl acetate. Also, methyl ethyl ketone in a pure form now costs only about one-fourth as much as methyl acetate of 95 per cent purity.

Reproducibility.—To test the reproducibility of the methyl ethyl ketone method of developer analysis, six analyses each were made of a production negative developer, a production positive developer, a high Elon-high hydroquinone type developer, a low Elon-low hydroquinone type developer, and the *SD-21* developer. The results of these analyses are shown in Tables 4 through 8.

TABLE 4

Production Negative Developer

Analysis Number	1	2	3	4	5	6	Maximum Deviation from Mean (Per Cent)
Elon (grams per liter)	1.63	1.63	1.63	1.73	1.69	1.72	3.6
Hydroquinone (grams per liter)	2.12	1.98	2.06	2.11	2.10	2.02	2.4

TABLE 5

Production Positive Developer

Analysis Number	1	2	3	4	5	6	Maximum Deviation from Mean (Per Cent)
Elon (grams per liter)	2.22	2.34	2.24	2.35	2.39	2.39	4.3
Hydroquinone (grams per liter)	7.31	7.71	7.55	7.33	7.71	7.61	3.2

TABLE 6

High Elon-High Hydroquinone Type Developer

Analysis Number	1	2	3	4	5	6	Maximum Deviation from Mean (Per Cent)
Elon (grams per liter)	3.22	3.22	3.22	3.31	3.13	3.31	3.4
Hydroquinone (grams per liter)	9.46	8.96	8.80	9.04	8.91	9.14	4.5

TABLE 7

Low Elon-Low Hydroquinone Type Developer

Analysis Number	1	2	3	4	5	6	Maximum Deviation from Mean (Per Cent)
Elon (grams per liter)	0.20	0.21	0.21	0.20	0.21	0.20	2.4
Hydroquinone (grams per liter)	0.33	0.31	0.32	0.33	0.33	0.33	4.6

TABLE 8

SD-21 Developer

Analysis Number	1	2	3	4	5	6	Maximum Deviation from Mean (Per Cent)
Elon (grams per liter)	1.93	1.87	1.93	1.87	1.93	1.93	2.0
Hydroquinone (grams per liter)	4.81	4.85	4.85	4.69	4.81	4.81	2.2

From Table 4 it is evident that the maximum deviation from the mean in six analyses of a production negative developer is 3.6 per cent for Elon and 2.4 per cent for hydroquinone. According to

TABLE 9

	Developer *1* in grams	Developer *2* in grams	Developer *3* in grams	Developer 4 in grams
Elon	2.0	3.0	0.22	0.31
Sodium Sulfite	100.0	40.0	64.9	39.6
Hydroquinone	5.0	10.0	0.28	6.0
Boric Acid	8.0	...	...	...
Borax	8.0	...	2.0	...
Sodium Carbonate	...	20.0	...	18.7
Citric Acid	...	...	...	0.68
Potassium Metabisulfite	...	...	...	1.5
Potassium Bromide	0.25	...	...	0.86
Water to make	1 liter	1 liter	1 liter	1 liter

Table 5, the maximum deviation from the mean in six analyses of a production positive developer is 4.3 per cent for Elon and 3.2 per cent for hydroquinone. In Table 6, it may be seen that the maximum deviation from the mean in six analyses of a high Elon-high hydroquinone type of developer is 3.4 per cent for Elon and 4.5 per cent for hydroquinone. According to Table 7, in six analyses of a low Elon-low hydroquinone type developer, the maximum deviation from the mean is 2.4 per cent for Elon and 4.6 per cent for hydroquinone. In

Table 8 it may be seen that in six analyses of *SD-21* developer the maximum deviation from the mean is 2.0 per cent for Elon and 2.2 per cent for hydroquinone. These reproducibility values indicate that the methyl ethyl ketone method of developer analysis is quite satisfactory for production control of developers.

Accuracy.—To test the accuracy of a method of developer analysis using methyl ethyl ketone, analyses according to the procedure just outlined were made of each of the four developers, mixed according to the formulas given in Table 9.

By inspection of Table 10, it may be seen that the methyl ethyl ketone method of developer analysis has an accuracy quite adequate for production control analyses of fresh developers.

TABLE 10

Developer Number		Grams per Liter Mixed	Grams per Liter Found	Per Cent Error
1	Elon	2.0	1.9	4.0
	Hydroquinone	5.0	4.9	1.8
2	Elon	3.0	2.9	4.2
	Hydroquinone	10.0	9.6	4.0
3	Elon	0.22	0.21	4.5
	Hydroquinone	0.28	0.29	3.5
4	Elon	0.31	0.30	3.2
	Hydroquinone	6.0	5.90	1.6

However, since these developers were all freshly mixed it was necessary to determine what effect the monosulfonates of Elon and hydroquinone might have on the accuracy of this method. Therefore, one gram per liter of Elon monosulfonic acid and one gram per liter of sodium hydroquinone monosulfonate, respectively, were added to developer *1* of Table 9. The resulting developers were analyzed and the data thus collected are shown in Table 11.

TABLE 11

	Developer *1*	Developer *1* plus one gram per liter Elon Monosulfonic Acid	Developer *1* plus one gram per liter Hydroquinone Monosulfonate
Elon	1.92	1.93	1.94
Hydroquinone	4.91	4.87	4.94

Reference to this table will show that the presence of monosulfonates in the developer apparently has little effect on the result of the analysis. Hence, it is concluded that the methyl ethyl ketone

method of developer analysis has satisfactory accuracy for production control.

Conclusions.—(*1*) It was concluded that methyl ethyl ketone is more satisfactory than methyl acetate or ethyl acetate as a solvent in the analysis of photographic developers for Elon and hydroquinone in the following respects:

(*a*) Methyl ethyl ketone when used with the *U*-tube extractor showed a better rate of extraction for Elon and hydroquinone than methyl acetate or ethyl acetate.

(*b*) Hydroquinone is more soluble in methyl ethyl ketone than in equal volumes of methyl acetate or ethyl acetate.

(*c*) Methyl ethyl ketone, in California, is more easily obtainable in a purer form than methyl acetate.

(*d*) Methyl ethyl ketone is only one-fourth as expensive as methyl acetate.

(*2*) Analyses made using methyl ethyl ketone as the extracting solvent showed this method to have the necessary accuracy and reproducibility for production control use.

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NAVAL TRAINING-TYPE EPIDIASCOPE FOR UNIVERSAL PROJECTION OF SOLID OBJECTS*

JACQUES BOLSEY**

Summary.—*The Special Devices Division of the Navy's Office of Research and Inventions conceived the idea of projecting the image of a solid model on a screen. For this particular trainer it was desired to project an airplane model on a spherical screen. Moreover, the image itself had to be movable so as to be positioned at any point on the spherical screen. Among the many problems which had to be overcome were depth of field, as in microphotography, the level of illumination, as in all epidiascopes, and finally the wide range of magnification.*

Many optical combinations were computed and tested, as well as a variety of light sources and condensing designs. The most suitable combination was adopted and built into the first model.

In its development of ever more realistic and flexible training devices, the Special Devices Division of the Navy's Office of Research and Invention commissioned us to build a new type of projector to project the image of a solid model airplane. The attitude of the airplane should be variable at will, allowing full freedom in pitch, roll, and turn, so that the airplane might appear to climb, dive, and roll. The image should be continuously variable in size in order to simulate continuous changes in range.

The Navy's requirement was to set up such a projector at the center of a spherical screen (similar to a planetarium screen, 26 ft in diameter). Means were also required to project the image anywhere on the spherical screen, and all of these variables were to be remote controlled.

The prescribed range of magnification was to be such that the airplane could appear at any distance from 300 to 4000 ft. This called for a variable focus optical system with a range of more than one to thirteen.

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** Bol, Ltd., New York.

It was obvious from the start that the greatest difficulty would be to get a sufficiently high light output, because, since the airplane was to be seen in any attitude (that is, head-on, from above, from below, *etc.*) a transparency or film strip was out of the question. The Navy wished to project a solid model. Moreover, a dark silhouette against

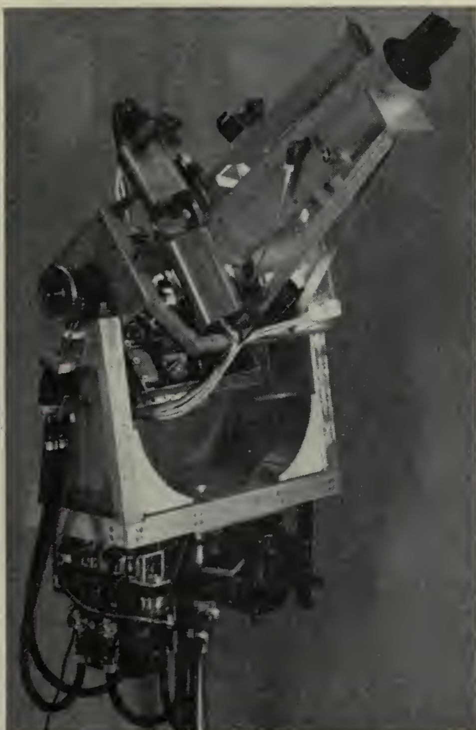

FIG. 1. Complete projector (front view, without covers).

a light background would not have been suitable; a light image was required in order to stand out on the screen when background effects such as clouds or sea were thrown on the screen by auxiliary projectors. The size of the model airplane was not specified but a maximum of one-inch wing span was chosen in order to avoid excessive length of the projection optics.

The level of illumination on the model would have to be extremely

high, since requirements showed that the relative aperture of the system could not be higher than about $f/20$.

Illumination.—A large number of known light sources were considered. The high-pressure mercury vapor tube is of course excellent in so far as total output is concerned, but the very elongated

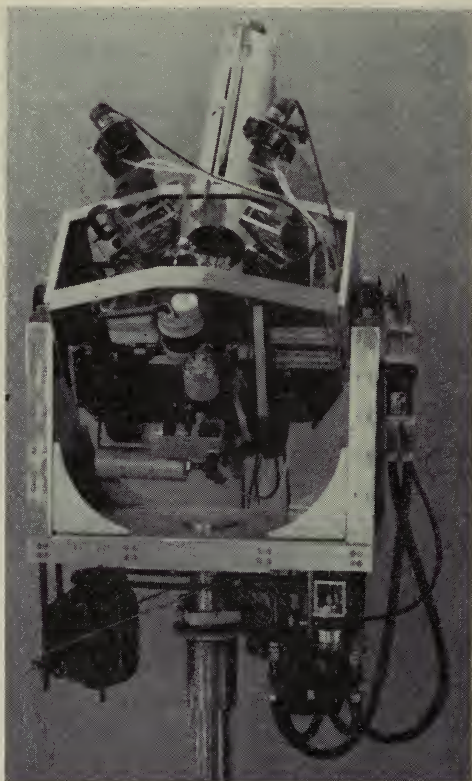

FIG. 2. Complete projector (rear view, without covers).

shape of this source was not suitable because the light had to be concentrated into a small circular area. Moreover, it required a fair bulk of auxiliary equipment which we wished to avoid.

At the other end of the scale, in lamps then available, the photomicrographic lamp is excellent for size and shape of the source, but its total output is such that dozens would have been required.

Several attempts were made to work out a means of bringing the model itself to incandescence. A thorium oxide model was made to glow in the flame of a welding torch. It was found that a tungsten model could be held at incandescence by a high-frequency coil. These methods were ruled out because of the element of danger in the open flame and of the high disintegration rate of the model and the difficulty of mounting the model under these conditions.

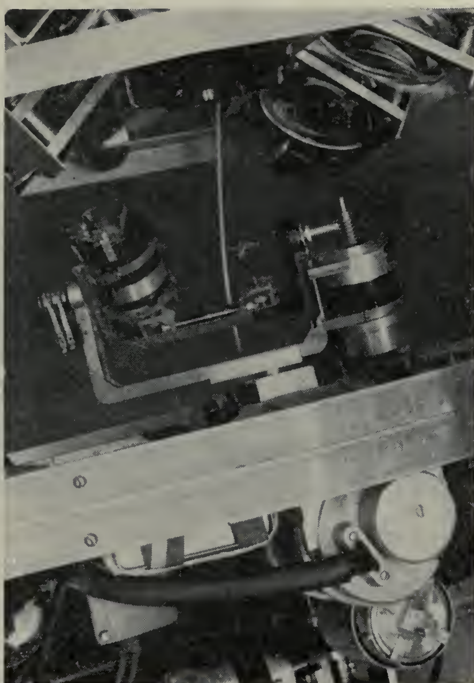

FIG. 3. Model suspension mechanism.

We investigated also a vacuum tube developed by the Flight Training Research Association in which a tungsten foil shaped like an airplane was brought to incandescence by electronic bombardment. The foil airplane lacked realism and the development on this tube had not at that time progressed to the use of a solid model.

Eventually, the light source that was adopted was the tungsten projection lamp. Its filament area is relatively small, its efficiency good, and it is reliable and available. It was found that the neces-

sary illumination could be obtained by using a suitable number of these lamps in high-efficiency condenser systems.

Arranged in a conical pattern around and in front of the model are six standard projection bulbs of 1000 w each. They all illuminate the same one-inch area and the concentration of light—and of heat—is extremely high. The projection lamps are, of course, designed to burn in a vertical or near vertical position. Our tests have shown, however, that if the lamps are well cooled, their life is still good when burned in a changing position as in this projector.

FIG. 4. Experimental optical system.

Model Suspension.—The problem of mounting the model so that its attitude could be varied at will led to the construction of several experimental setups.

In one the airplane was supported by a tiny ball joint on the end of a thin rod; other rods were similarly attached to the tail and one wing. The airplane could thus be controlled from below, much as a marionette is controlled from above.

Another system considered consisted in mounting the model in the center of a transparent sphere. This had the advantage that no supporting members were visible at any time. However, the control for pitch, roll, and turn of the model would have been so complicated that it was abandoned. Also the heat radiated by the lamps and concentrated in the center of the sphere required a complicated and bulky heat evacuation system.

All in all, a gimbal mount was found simplest and most efficient. Inside the projector the model, which is easily interchangeable, is supported on a slender shaft in a gimbal mount. Differential gear trains are eliminated by placing the two smaller Selsyn motors on the gimbals themselves. This mechanism being relatively light, no servo system is required, and the three Selsyns control pitch, roll, and turn.

Optical System.—In developing the optical system the prime considerations were light transmission and over-all length. The magnification had to be varied in the ratio of one to thirteen, which called for a new type of very high ratio lens. The image on the screen is 40 in. in wing span at the highest magnification, and 3 in. at the lowest; the equivalent focal lengths are consequently 3.7 in. and 29.25 in., yet this maximum equivalent focal length of almost 30 in. must be obtained in a system as short as possible. The design which was incorporated in the projector has a mount 27.5 in. long and comprises only two optical groups. It will operate at apertures up to $f/9$, but as stated previously it is diaphragmed to $f/20$ at maximum magnification in order to reproduce the full depth of the model with sufficient sharpness.

The lens groups are assembled in telescoping tubes in the pointed end of the egg-shaped housing. The simplest means to co-ordinate the movement of these two lens groups is a differential cam which varies the space between them as the rear group is driven forward or back. This cam is mounted above the lens tube and a bell crank transmits the change in spacing by means of a gear sector and rack. The assembly is finally spring-loaded to avoid all backlash.

As with the optical system, the condenser units were thoroughly studied in order to reach an efficiency as high as possible for this particular device. Each unit consists of only two elements aside from the spherical reflector; it accepts a 65 deg cone and condenses the light to an area of one-inch in diameter. All lenses and condensers are coated for maximum light transmission.

Zenith and Azimuth Control.—In order to move the image in zenith and azimuth on the screen, it was decided to swing the whole projector. This avoided the loss of light which would occur in a stationary projector equipped with mirror or prism systems for zenith and azimuth movements of the image. The projector proper, which is somewhat egg-shaped and measures 45 in. in length and 24 in. in diameter, is mounted in a yoke so that it may be pointed 20 deg below the horizon, raised to a vertical position, and swung over on its

back, down again to 20 deg below the horizon. This gives the zenith of the image.

The yoke rotates around a vertical axis for azimuth. Both movements are worm gear driven. Since the image must be positioned at any point on the screen by remote control, a servo system is used to rotate the projector around these axes. An all-aluminum construction was adopted to lighten the structure and facilitate these movements.

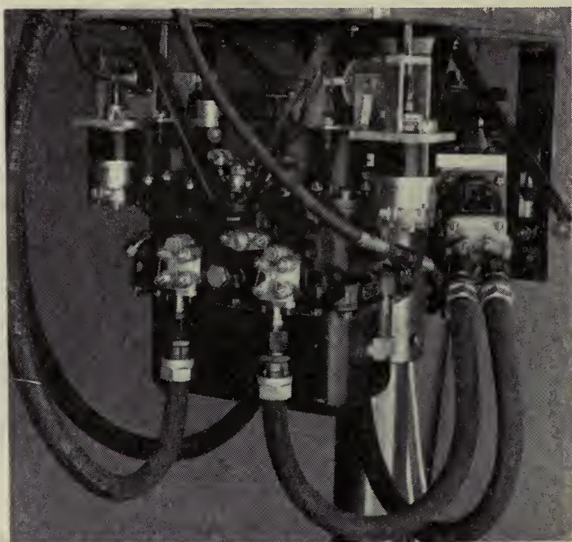

FIG. 5. Servo-mechanism for azimuth and elevation.

The servo-system consists of a variable speed hydraulic unit of the type used in standard aircraft turrets, the booster valves of which are controlled by Selsyns.

The response is practically instantaneous and the maximum speed of rotation of the projector is 26 rpm. If the airplane represented is at 300 ft, a crossing speed of 550 mph can be represented. The zenith drive is equipped with a limit mechanism which acts directly on the booster valve.

Range Control.—To meet the Navy's specifications, the range control must be such that speeds up to 50,000 ft per min may be simulated with low response delay and high accuracy. The

change in magnification was obtained by the vario-lens system previously described. A hydraulic system was adopted to drive the vario-lens because it delivers a great range of speeds with immediate response. It is mounted on the bulk head behind the model support assembly and is powered by constant speed electric motor of $^1/_3$ hp. The lens assembly can be driven its full 17 in. of travel in 6 sec in either direction; the closing speed represented can also be brought down to zero and reversed immediately without any lag. The booster valve on the hydraulic unit is controlled by a Selsyn motor; when the lens assembly reaches the end of its travel this Selsyn is overpowered by a limit mechanism to prevent damage to the apparatus.

These hydraulic units are normally equipped with a breather which allows the oil to expand as it warms up in the course of running, and any bubbles to escape. In this application the breather is replaced by expansion chambers so that no oil spillage will occur and no bubbles will be trapped as the unit rotates to varying positions with the projector.

Power.—The entire machine is operated on 110 v, a-c single phase, and requires about 7 kw power.

Remote Controls.—Besides the two motors which power the hydraulic servo-systems, in all, six Selsyns are built into the machine; one for zenith and one for azimuth movements, one for the range control drive of the vario-lens, and one each for pitch, roll, and turn of the model. Each of the Selsyn motors is connected to its Selsyn generator on the control panel. This panel controls the movement of the airplane.

Acknowledgment.—We wish to express our appreciation to the Special Devices Division of the U. S. Navy Office of Research and Inventions for their assistance, encouragement, and advice which helped us greatly in the development of this device.

A NEW METHOD OF COUNTERACTING NOISE IN SOUND FILM REPRODUCTION*

W. K. WESTMIJZE**

Summary.—*Reproduction of the sound recorded on sound film is usually accomplished by means of a narrow beam of light thrown upon the film in a direction perpendicular to that in which the sound track is moving. The fluctuations in the light flux passed through are converted into sound. With this method a noise results which is caused by the fact that part of the light passed through is intercepted by specks of dust, scratches, etc., on the sound track, especially when the film has already been used several times. This article describes a method of counteracting this noise in cases where the sound is recorded as so-called amplitude writing. The beam of light is replaced by a series of equidistant light spots moving with great velocity perpendicular to the sound track. In addition to the theoretical fundamentals of the method, a practical form of application is also discussed.*

The Ordinary Method of Reproduction.—The reproduction of sound film is usually reproduced in the following manner. A narrow beam of light is thrown on the film perpendicular to its direction of motion. Confining ourselves to the case where the sound is recorded as so-called amplitude-writing, such as, for example, with the Philips-Miller film,[1] the quantity of light passing through the film depends upon the width of the sound track (and of course of the beam). The light passes through to a photocell and is converted into an electric current which may be considered as a direct current upon which an alternating current is superposed. The magnitude of this direct current depends upon the width of the so-called zero track, *i. e.*, the track which is made when no sound vibrations are being recorded. The zero track is unavoidable, since otherwise modulation would be impossible. It is easy to understand that its width must be equal at least to once or twice the maximum modulation amplitude, according as the modulation takes place on one side or on both sides of the track.

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* Reprinted from *Philips Technical Review*, **8**, 4 (Apr. 1946), p. 97.

** Research Laboratory, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.

The alternating current depends upon the modulation of the track and thus on the sound vibrations recorded, and if the light beam were infinitesimally narrow the trend of this current would be an exact copy of the sound vibrations. Actually the beam has a finite width Δ, but even so the relation between the sound vibrations recorded and the corresponding vibrations of the light flux can easily be determined. Let us assume that the sound track is modulated by one harmonic vibration. Such a vibration is represented in Fig. 1.

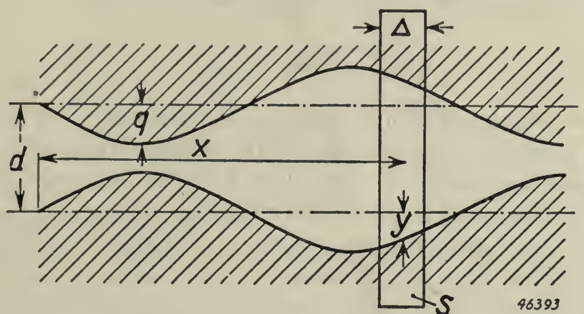

FIG. 1. Diagram of the usual method of scanning. The film with the modulated sound track travels past this beam S. The variations in the light flux passed through are registered by a photocell. In the diagram the track is modulated on both sides by a purely sinusoidal vibration; d = width of the unmodulated track, q = amplitude of the vibration with which the track is modulated, y = depth of modulation at the point with the abscis x, Δ = width of the slit.

When this vibration corresponds to a tone of ν oscillations per sec, and when the velocity at which the film is traveling is v cm per sec, there are ν/v vibrations per cm of film and the vibration can be represented by the equation $y = q \cos 2\pi\, \nu/v.x$ where y is the depth of modulation and x the length of film passed, measured from an arbitrary zero point. The amount of light passed through is then proportional to

$$\Delta \cdot d + 2 \int_{x - {}^{1}/_{2}\Delta}^{x + {}^{1}/_{2}\Delta} q \cos\left(2\pi \frac{\nu}{v} \xi\right) d\xi = \Delta \cdot d + \Delta q \cdot \frac{\sin \pi \frac{\nu}{v} \Delta}{\pi \frac{\nu}{v} \Delta} \cos 2\pi \frac{\nu}{v} x$$

d representing the width of the zero track. From the result it is immediately clear that a d-c and an a-c component are present, while it is also clear that the amplitude of the a-c component is multiplied

by a factor which depends upon the frequency ν. This factor

$$\frac{\sin \pi \frac{\nu}{v} \Delta}{\pi \frac{\nu}{v} \Delta}$$

is equal to unity when $\nu = 0$, and then decreases. In order that the highest frequencies to be reproduced should not be attenuated by more than about 3.5 db compared with the lowest (such an attenuation is still permissible) it is necessary that

$$\pi \cdot \frac{\nu_{\max}}{v} \cdot \Delta < 1.5.$$

With $\nu_{\max} = 8000$ and $v = 32$ cm per sec this results in $\Delta < 0.002$ cm. The light-beam may therefore not be wider[2] than 20 μ.

When there are specks of dust or dirt on the sound track or when it has been scratched, as is particularly the case with much used sound films, these tiny specks and scratches, irregularly distributed over the surface of the film, cause a noise. They cannot, however, be observed individually, as is the case with larger particles ($< 80\ \mu$), which cause an annoying ticking or bubbling sound. It would mean a considerable improvement in reproduction if this noise could be avoided.

For some time already a system has been in use which diminishes this noise. It is based on the following principle. The noise is most annoying during the soft passages, *i. e.*, when the depth of modulation is slight. In sound recording it is now arranged, by means of suitable connections, that during these passages the zero track becomes narrower, thus reducing the area upon which the troublesome specks or scratches may occur and thereby also the noise. During the louder passages the zero track again becomes wider, and thus also the noise becomes louder, but this is less troublesome here because for the greater part it is drowned out by the music or speech.

This method, therefore, does not eliminate the noise, but only reduces it during the soft passages.

Principle of High-Frequency Scanning.—We have seen that in the scanning method described above the noise is caused by contaminations on the transparent part of the film between the two edges of the sound track. This phenomenon therefore also occurs when the edges of the track, which actually represent the sound, are ideal. With the method of high-frequency scanning, about to be discussed, only the edges of the track are scanned; the influence of the part

between the edges is eliminated and thus also the noise, so far as it is caused by specks on the transparent part of the film. Of course the noise resulting from imperfections in the edges of the sound track, to which we shall return later, still remains, just as with the method of zero track adaptation discussed above.

With this method of scanning, instead of a narrow slit of light, we have a series of light spots moving at a very high velocity and at regular intervals perpendicularly across the film. Since the sound track is also moving, the light spots actually move in an oblique

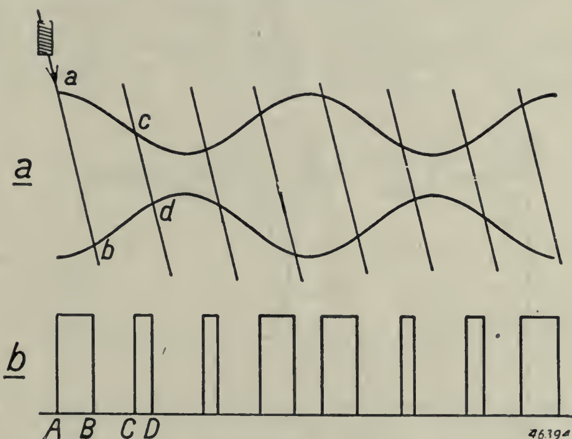

FIG. 2. Diagram of the high-frequency method of scanning. A series of equidistant spots of light travel at a high velocity across the film. Owing to the fact that the film is also traveling at the same time, the light spots describe paths which are oblique with respect to the film and which are given in Fig. *a*. The slope of these paths is very much exaggerated for the sake of clearness. As long as a light spot is inside the edges of the track, a current flows in the photocell. The form of the signal leaving the photocell is shown in Fig. *b*. The block *AB* corresponds to the path *ab*, *etc.*

direction across the film. Here, too, the light passing through falls on a photoelectric cell, which gives a current impulse during the time that the light spot is moving between the edges of the track. The image of this impulse is approximately rectangular. The intensity of the impulse is determined by the intensity of the beam of light employed. The duration of the impulse depends upon the width of the track at the point where the light spot crosses it. Thus in Fig. 2 *AB* in the lower half corresponds to *ab* in the upper half,

the same being true of CD and cd, *etc.* It is essential to note that *the beginning and end points of the blocks* are fixed by the *edges of the* sound track. (For the sake of clearness the obliqueness of the paths of the light spot across the film is exaggerated.) Contaminations on the film are manifested by variations in the beam of light passed through and consequently the image of the current impulses is not actually as shown in Fig. 2b, but as in Fig. 3; between A and D the current is not constant, variations occurring of an accidental nature. The great advantage achieved lies, however, in the fact that the disturbances are separated from the phenomenon to be reproduced, the former affecting the height of the blocks, while the latter only affects the beginning and end points of the blocks. Therefore the disturb-

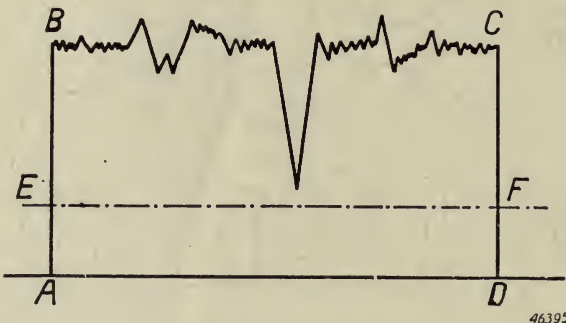

FIG. 3. Image of a current impulse from the photocell. The intensity variations are due to contaminations on the film in the path of the scanning light spot. The essence of the method lies in the fact that the influence of the contaminations can be eliminated by passing the signal through a limiter. Limitation to the level EF would in this case be sufficient.

ances can easily be eliminated by sending the whole signal through a limiter which only passes signals up to a certain amplitude. In this way the disturbances are, as it were, cut off. For the current variation shown in Fig. 3 a limitation to the level EF would be sufficient to bring about this elimination. If the signal is afterwards so amplified that the amplitude is increased in the ratio BA/EA, a signal is obtained which is absolutely identical with what would have been obtained if the sound track had been everywhere uniformly transparent.

We must now consider the question as to how we can derive the

original sound frequencies from the block-signal. The frequency spectrum of this signal must first be investigated. This involves complicated calculations which will be further dealt with on another occasion. Suffice it here to go into a few qualitative considerations. Let us first examine the unmodulated signal. It consists of congruent blocks having a frequency μ (the scanning frequency). If a Fourier analysis is made of this signal, vibrations with the frequencies μ, 2μ, 3μ, *etc.*, are obtained. If we now modulate the block signal with a frequency ν, secondary frequencies then appear in the spectrum: $\mu \pm \nu$; $\mu \pm 2\nu$; $\ldots 2\mu \pm \nu$; $2\mu \pm 2\nu$; $\ldots 3\mu \pm \nu$; *etc.* It is, however, quite obvious that also the frequency ν itself will occur. Let us again consider Fig. 2. The blocks corresponding to the wide parts of the track are wide and consequently the wide parts give rise to relatively long current impulses with short interruptions. In the case of the narrow parts of the track it is just the reverse. If we now pass this signal through a suitable filter, *i. e.*, a low-pass filter, with limiting frequency coinciding with the highest frequency that has to be passed through, the result is that the signal, roughly speaking, is replaced by a progressive average over a certain time interval approximately of the order of one-quarter of the time of vibration of the limiting frequency. Thus in each case a number of successive blocks is averaged and the result is a signal which is strong when the blocks are wide and weak when they are narrow, thus an alternating current with a frequency ν corresponding to the frequency of the vibration originally registered.

For reproduction it is essential that the frequency ν should occur but that 2ν, 3ν, *etc.*, should be absent. That this is indeed the case is proved by calculation, though it is not easy to imagine. It is obvious, however, that this is of importance, for, as a rule, with ν also 2ν and possibly 3ν, *etc.*, lie in the audible range.

We can now also make it clear that the scanning frequency μ must be much greater than the highest frequency ν to be reproduced, because in addition to μ owing to the modulation also the tones $\mu - \nu$, $\mu - 2\nu$, *etc.*, occur. These tones become weaker as we get farther away from the frequency μ.

Calculation shows that the frequency $\mu - 5\nu$ is already 60 db weaker than the frequency ν. The frequency $\mu - 4\nu$ would still be strong enough to be disturbing. If we are to eliminate this by means of a filter, then it must fall outside the audible range, and this means that:

$$\mu - 4\nu_{\max} > \nu_{\max}, \text{ or } \mu > 5\nu_{\max}$$

where $\nu_{\max}$ represents the highest frequency of the audible region which is to be reproduced. Taking $\gamma_{\max} = 8000$ c per sec, it follows that $\mu = 40{,}000$ c per sec.

Limitations of the Effect of the Method.—It must be pointed out that not all disturbances can be eliminated in the manner described. Two cases must be examined separately.

In the first place a contamination may be so large and consequently intercept so much light as to cause the photocurrent to fall below the value that passes through the limiter. The result is a "dent" in the corresponding block which again causes a disturbance.

This is especially the case when the light is entirely cut off by the contamination, in which event one light spot produces two current impulses (blocks). However, by giving the light spot an oblong shape it is possible to ensure that this case seldom occurs. Already in the beginning of this article it was observed that the width of the light beam in the ordinary method of scanning may not be more than 20 μ, because otherwise the high tones would be weakened. This applies also for the width of the light spots, but not for their height. (By width we mean here the dimension perpendicular to the motion of the light spots and by height the dimension parallel to that motion.) An increase in the height, for instance to 100 μ, has by first approximation the same effect on the fluctuations of the transmitted light flux as if the zero track had been taken $100 - 20 = 80$ μ wider and the height left the same. This can easily be explained: Owing to the finite height of the light spots the photocurrent impulses do not have the form of rectangles (apart from the disturbances due to contaminations), but of equilateral trapezia.

During the time that the light spot is moving over the edge of the track, the intensity increases from zero to the maximum value and decreases again from the maximum to zero. In Fig. 4 two cases are depicted for different heights of the light spots. It is assumed that they begin to pass over the track at the same moment. The photocurrent impulses then begin at the same moment for both, at the point A. We further assume, of course, that the two light spots move at the same velocity, so that the light intensity increases in the same way and the trend of the photocurrent will be the same in both cases, for instance along AB. A difference occurs only when the lowest light spot is completely over the track, let us say at B. From that moment the corresponding photocurrent (except for disturbances)

remains constant. For a short while, however, the current corresponding to the highest spot continues to increase at the same rate, until this spot is also entirely over the track, let us say at B', from which moment the second current, too, is (practically) constant.

As soon as the upper edge of one of the spots has reached the other side of the track, the corresponding current begins to decrease again.

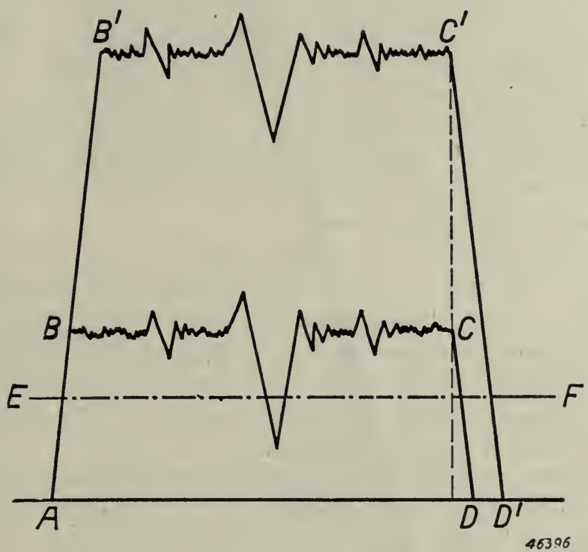

FIG. 4. Influence of the height of the light spots on the form of the photocurrent impulses excited by the light spot. Owing to the fact that the spot has a finite height, some time elapses before the whole spot is over the track. During that time the current increases continually. The impulse $ABCD$ is due to a low spot, the impulse $AB'C'D'$ to a higher one, the top side of both spots having reached the edge of the track at the same moment. In the second case the average current of the photosignal is larger. Limitation of the signal to the level EF is therefore sufficient to eliminate all disturbances in the second case but not in the first case.

Under our assumptions this will take place at the same moment for both currents and the points at which this takes place, namely C and C', lie vertically above each other. The decrease is at the same rate as the increase and thus equal for both spots (the current curves are equilateral trapzeia). The currents thus decrease according to two parallel straight lines, $CD//C'D'$. Therefore they do not end at the same moment. The difference DD', however, is entirely determined

by the difference in intensity CC' (and the velocity of the spots, which is however, the same for both), and this in turn depends exclusively on the difference in height of the spots.

If we pass the two signals through the same limiter then from our reasoning it follows that the signals finally obtained differ only in length, but that this difference is the same for all blocks and therefore has no effect on the sound to be ultimately reproduced. It only alters the d-c component of the photocurrent signal, just as a change in the width of the zero track would do, and this is suppressed by a filter. If the height of the spot is greater than the width of the track, the situation is somewhat different, but a closer investigation shows that in this case too the length of the blocks of the limited signal, except for a constant, is proportional to the width of the track at the place where the light spot passed.

From the foregoing it will be clear that it is possible to choose such a height of the spot that, practically speaking, the transmitted light cannot be cut off by contaminations to such a degree that after limitation such disturbances still have any effect. This is in fact demonstrated in Fig. 4. The absolute changes in intensity of the transmitted light beams resulting from contaminations are the same for both spots. Therefore the noise assumed to be present in this case is without influence on the limited signal with the higher spot, but with the lower spot it does leave a disturbance in the limited signal.

The second possibility of disturbances occurs when a contamination lies exactly tangent to or across the edge of the track. This alters the form of the limitation. The disturbance caused by such an imperfection in the edge of the track is not eliminated by the method discussed here. The chance of such a disturbance occurring, however, is slight compared with that caused by a speck elsewhere on the track. The modulated track is at least 1 mm wide, so that the chance of contaminations, even of the size of 100 μ, coming to lie at the edge is only 20 per cent; most contaminations, however, are much smaller and there is therefore still less chance of their lying at the edge of the track.

One Possible Construction of the Apparatus.—The above-described high-frequency scanning can be realized in different ways. In the first place, the sound track can be scanned by a moving light spot, as has been assumed in the foregoing. In principle the same results can be attained by projecting the image of the sound track and causing this image to vibrate with respect to a diaphram. In

both cases we may consider the vibration as being brought about with a moving light source and a stationary optical system, but also with a stationary light source and a moving optical system. Finally the vibrations may be construed as being brought about by electrical means as well as by mechanical means. We shall here confine ourselves to the description of a method worked out by us in which the scanning is accomplished with a moving light spot obtained from a mechanically moved optical system.

In Fig. 5 a diagram is given of the arrangement employed. The light from a linear source is projected by a lens several mm from the edge of a disk which can be rapidly rotated. In this disk radial slits have been sawed beginning at the edge. When the disk is rotating rapidly, therefore, each slit allows a fraction of the light from the

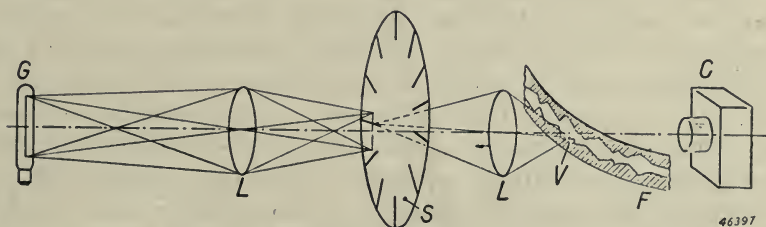

FIG. 5. Diagram of the setup for high-frequency scanning. G = source of light with linear filament. L = lenses. S = rotating disk with slits. F = film with modulated sound track. V = light spot. C = photocell.

image to pass through. The image of the illuminated opening is focused on the sound film by means of a second lens. The light passed through the sound track falls on a photocell and gives rise to the photocurrents already mentioned.

The practical realization of such a setup involves a number of technical difficulties which we shall now discuss.

The Choice of Light Source.—We have already remarked that the width of the light spot on the film may not amount to more than 20 μ. Furthermore, it must be very sharp (the transition from light to dark must take place within a distance of not more than a few μ) and not only when the projection is along the axis of the system, but also when the image is about 1 mm above or below it. Finally the light must be of sufficient intensity to excite a reasonably amplifiable photocurrent. These conditions make certain demands on the optical system and the source of light.

Linear light sources whose incandescent body is narrower than 80 μ are difficult to produce. This implies that the optical system must be a reducing one. The same conclusion is reached from the requirement of sharpness of projection. A fivefold reduction suffices for both requirements. This reduction is mainly effected by the second lens. The first lens gives practically an image of 1:1. The requirements for sharpness of the image make it necessary to work with small opening angles.

Finally from the minimum required light intensity of the beam that falls upon the photocell and from the dimensions of the optical system it is to be deduced that the brightness of the light source employed must be at least 1000 candle power per cm.^{2} In order to satisfy these requirements a special lamp was constructed.

Construction of the Rotating Disk.—The greatest difficulty lay in the construction of the disk. As already mentioned, the required frequency of the light spots is 40,000. The width of the track for Philips-Miller film can be set at a maximum of 1.6 mm, hence a velocity of the light spots of 6400 cm per sec. Since, as mentioned above, the second lens reduces by a factor 5, this leads to a peripheral velocity of the disk of 32,000 cm per sec. Now the peripheral velocity determines the stresses occurring in the disk. Similar disks of different diameters but with equal peripheral velocities exhibit exactly the same stresses at corresponding points. At a velocity of 32,000 cm per sec, these stresses are enormous and approach the yield point. It is clear that this sets an upper limit for the velocity. In fact, if this limit is reached the disk flies to pieces.

Since for different materials under otherwise similar conditions the stresses are proportional to the specific weights, a material had to be found with the most favourable ratio of yield point to specific weight. Moreover, having regard to the motive power for the disk, the material had to be electrically conductive, so that practically only duralumin and electron could be considered. Furthermore, since the highest stresses occur where the hole is drilled for the spindle, the disk was given a very slightly conical profile.

It can then be calculated that both for dualumin and for electron the maximum stresses occurring, even at a velocity of 40,000 cm per sec, still remain below half the yield point value. This was in fact confirmed experimentally by investigating at what peripheral velocity a test disk flew to pieces. This was found to be at 60,000 cm per sec (the stresses are proportional to the square of the velocity).

Furthermore, as it was desirable not to make the apparatus too cumbersome, the disk could not be made too large. Its radius was therefore fixed at 5 cm. This means that a speed of rotation of $32{,}000/10\pi = 1000$ rev per sec is required. Since the slits have to be about $5 \times 1.6 = 8$ mm apart, $10\pi/0.8 =$ approximately 40 slits can be made on such a disk. They are 0.6 mm. wide and 3.5 mm long (from this it follows that the length of the light spots on the film is 120 μ). The cutting of the slits requires much care.

In the first place they have to be spaced at exactly equal distances and must be exactly alike, as otherwise the frequency of revolution of the disk appears in the frequency spectrum, and since this lies in the audible region there will be a whistling tone in the sound reproduced. The scanning frequency, which is 40 times as high, lies, as we know, outside this region.

In the second place very careful finishing is essential because otherwise at the high speeds of rotation the disk might crack at the slits. For that reason before the slits are cut small holes are drilled at the spots where the slits end.

Bearings and Motive Power of the Disk.—With the above-mentioned very high number of revolutions of 1000 per sec special demands are of course made of the bearings. Even a slight eccentricity of the center of gravity of the disk with respect to the center of the bearings gives rise to enormous centrifugal forces as the speed increases, resulting in high pressures on the bearings, vibration of the motor, high friction and heavy wear. In order to avoid this the principle of the de Laval shaft was employed, with a thin flexible spindle instead of the usual rigid shaft. Owing to the centrifugal force the spindle will sag already at a low number of revolutions, and this sag becomes greater as the speed of rotation increases. When a certain speed is reached, the so-called critical speed, the sag will theoretically even be infinite. Above that speed the sag decreases rapidly and at the limit for infinitely high speed the disk will rotate about its center of gravity. When this state is reached the sage of the spindle and consequently the pressure on the bearings is very small. The bearing pressure is then mainly determined by the disk's own weight.

A difficulty in working with a de Laval spindle lies in the passing of the region of the critical frequency when starting up. It is possible to do so without breaking the spindle if that region is passed so quickly as to leave no time for the disk to assume large deflections.

In our case, however, the driving couple was not large enough for this and we therefore decided to suppress the dangerously large deviations by applying a suitable damping arrangement to the spindle. For that purpose the spindle is passed through eyelets at a short distance from the disk on either side. These eyelets are connected by rods to small pistons moving up and down with a little play in small cylinders containing oil. By this means the lateral movements of the disk are damped, and by choosing suitable dimensions for this device the vibrations in the critical region can be kept sufficiently low. Once the critical region is passed, the disk runs very quietly and speeds of 1000 and 2000 rev per sec are easily attainable.

As already remarked in passing, the disk is driven electrically. It is placed in the field of two mutually perpendicular magnetic circuits activated by alternating currents with a frequency of 1500 c per sec and shifted 90 deg in phase with respect to each other. Each circuit consists of two pole shoes, between which air gaps of about $^1/_2$ cm have been cut. The disk is placed in these air gaps. The combination of the two alternating magnetic fields produces a rotating field which turns the disk—made of a conducting material especially for this purpose—and is able to give it sufficient velocity. In order to minimize friction the disk with the complete driving mechanism is placed in an air-tight housing, so that it can function in a vacuum.

The Limitation of the Signal and Its Conversion into Sound.—The current impulses from the photocell, which are of the order of 10^{-7} A, are first very strongly amplified. For this purpose a wide-band amplifier is used which gives amplication constant within 6 db in a region from 30 to 500,000 c per sec. These voltage impulses are modulated, in the first place by fluctuations resulting from contaminations on the sound film, but in addition a noise connected with the powerful amplification is superimposed on the whole signal.

As has already been mentioned in discussing the principle of the method, these disturbances are eliminated by limiting the signal. For this purpose a pentode with high anode resistance is used. As is known, by introducing a sufficiently high resistance in the anode circuit of such a valve the $I_a - V_g$ characteristic can be made to assume the shape[3] of the curve k in Fig. 6. If, then, we apply to the valve a negative grid voltage so high that $I_a = 0$ even for the most powerful disturbances occurring, in the absence of a signal, and make provision for the signal, on the other hand, to be so powerful as always to generate the maximum anode current, likewise for the most power-

ful disturbances, then the object has been attained. (See Fig. 6).

Finally the signal prepared in this manner needs only to be sent through a filter that allows the frequencies of the audible region to pass through and eliminates all the others. It may then be fed to the loudspeaker *via* a power pentode.

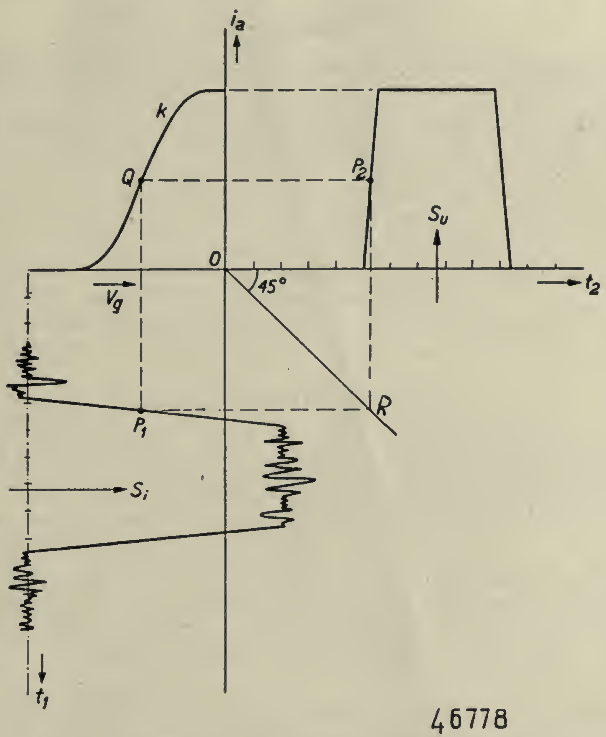

FIG. 6. Diagram of the double limitation of the photocurrent signal by means of a pentode. S_i = incoming signal showing disturbances caused by contaminations on the film and disturbances caused by the powerful amplification. S_u = outgoing signal. k $i_a - V_g$ = characteristic of the pentode. Starting from an arbitrary point P_1 of S_{u1} the corresponding point P_2 of S_u can be constructed with the aid of the auxiliary points Q and R. Since the time units on the t_1 and t_2 axes are similar, OR cuts the angle between the t axes through the center.

Conclusion.—By means of the method of counteracting noise described here it is possible to obtain a perceptible improvement in quality of the sound reproduced. At the present stage of development the improvement in the case of new films, which are

therefore practically free of contamination, is of no significance. In the case of films which have been used several times, however, the improvement is considerable. The method described thus makes it possible to use a film much longer than was previously possible, with retention of the original quality.

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[1] For a description of the Philips Miller system, see *Philips Tech. Rev.*, **1** (1936), pp. 107, 135, 211.

[2] SCHOUTEN, J. F.: "Synthetic Sound," *Philips Tech. Rev.*, **4**, (1939), p. 167.

[3] *Cf.* also *Philips Tech. Rev.*, **5** (1940), p. 61.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION MEETING

The first fall meeting of the Atlantic Coast Section of the Society was held at the Hotel Pennsylvania on October 16. Frank S. Cillier, Associate Director of Research, Encyclopaedia Britannica Films, Inc., presented a most interesting paper entitled "Blueprinting the Classroom Film."

Following the showing of a 16-mm motion picture, *Using the Classroom Film,* Dr. Cillier described the unique characteristics developed by the classroom film in the 20 years since the advent of sound. He drew conclusions regarding classroom film research, writing, production, and distribution from the practical experiences of classroom film producers, here and abroad, and in the light of present-day trends. Dr. Cillier showed two typical classroom films.

Interesting questions and answers developed in the discussion period which followed. The paper will be published in a subsequent issue of the JOURNAL.

MIDWEST SECTION MEETING

Three speakers addressed the October 10 meeting of the Midwest Section of the Society held in Chicago. Jack Kielty described the special problems of making a traffic safety documentary 16-mm film, *X Marks the Spot.* A showing of the film, which was produced by the Jam Handy Organization for the State of New Jersey, opened the meeting.

Clyde R. Keith, Chairman of the American Standards Association Sectional Committee on Motion Pictures Z22, spoke on the work of the American Standards Association in processing motion picture standards. The democratic structure of the committee was emphasized and the procedure for establishment of a standard was described.

John Boyers, assisted by R. J. Tinkham of Magnecord, Inc., Chicago, presented a paper on "High-Fidelity Magnetic Recording for Motion Picture Production." The decision to drive the 0.004-in. OD wire by a flywheel capstan was explained, as well as details of magnetic head construction. An enjoyable demonstration included musical passages, direct playback, echo and other effects.

The last two papers were also presented at the Hollywood Convention and will appear in the JOURNAL.

INCREASE IN MEMBERSHIP DUES

Personal letters were recently mailed to all Associate and Student members of the Society by M. R. Boyer, Financial Vice-President, announcing an increase in annual membership dues. At the meeting of the Board of Governors held during the 60th Semiannual Convention in Hollywood, it was brought to the attention of the Board that our present Associate and Student membership dues were insufficient to cover the increased cost of JOURNAL publication and administration.

The Board, therefore, took the only action possible and voted to raise the dues of Associate members from $7.50 to $10, and of Student members from $3 to $5, annually. Bills for 1947 dues for these two grades, therefore, will show this increase.

At this time, Mr. Boyer would like to urge the many Associate members who are eligible for Active membership to consider applying for this higher grade membership in the Society. Many members find that active participation in Society affairs materially increases the value of the Society to them and their companies. Since only members in the higher grades are eligible to vote and hold office, opportunities for participating in Society affairs are obviously better for members in the Active grade.

INCREASE IN JOURNAL SUBSCRIPTION RATE

Owing to increased costs of JOURNAL publication and administration, the Board of Governors of the Society has voted to raise the nonmember subscription rate to the JOURNAL from $8 to $10 annually, effective January 1, 1947. Single copies will be increased to $1.25 each. The Board also voted to discontinue discounts for subscriptions and single copies received through accredited agencies, effective January 1, 1947.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 47 **DECEMBER 1946** **No. 6**

CONTENTS

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† See special notice on page 528.

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Vol 47 DECEMBER 1946 No. 6

SENSITOMETRIC CONTROL OF THE DUPING PROCESS*

J. P. WEISS**

Summary.—*Because of head-and-tail development effects, sensitometric exposures of the standard type cannot be wholly relied upon to give a true indication of picture contrast. A method is described whereby sensitometric exposures of unusual form can be used to establish processing techniques for making dupes. Good correlation with visual judgment of quality of a standard picture is obtained.*

In testing films designed for use in the duplicating process, we in the du Pont Laboratory have considered it desirable to make a sensitometric evaluation as well as a practical picture duping test. The latter tells us if the over-all result is good, but only the former can give quantitative information on how close the match is at all density levels throughout the picture. Unfortunately, ordinary sensitometry falls short of providing a true measure of film performance and of the conditions for obtaining most accurate reproduction. This undoubtedly has been the experience of everyone who has tried to use ordinary sensitometric methods in the selection of processing conditions for making dupes.

Confining our discussion to exposures made with intensity-scale sensitometers exclusively, the chief source of error in ordinary sensitometry is the development phenomenon variously known as "Eberhard," "area," or "neighborhood" effect. In the case of unidirectional development in a continuous developing machine it is called the "head-and-tail" or "directional" effect. Briefly reviewed, it is the fact that the density produced at any given point on a film depends not only upon the exposure at that particular point and the processing, but also upon the densities of the adjacent areas. Re-

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** Technical Division, Photo Products Department, E. I. du Pont de Nemours & Co., Inc., Parlin, N. J.

action products from the developing process tend to inhibit further development. If an exposed area follows high densities through a continuous developing machine, the resulting high concentration of development products streaming over the area will cause it to have lower density than if it had been preceded by unexposed emulsion. Vigorous agitation minimizes this density depression by sweeping away these reaction products, but in most cases not enough agitation is provided in a motion picture developing machine to eliminate the effect entirely.

The physical form of the usual sensitometric exposure causes it to be particularly susceptible to modification by the directional effect.

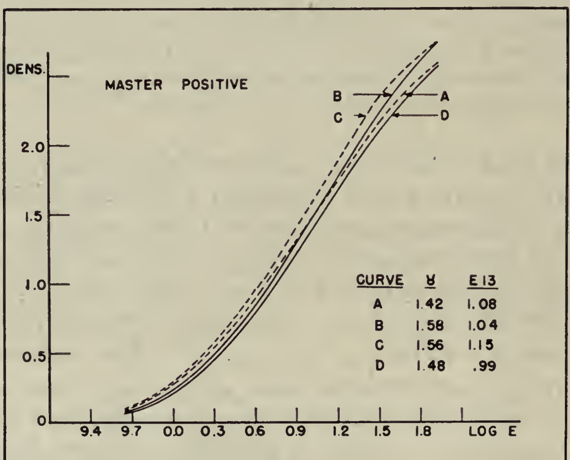

FIG. 1. Varying sensitometric data from a single film.

Ordinarily it consists of relatively large exposure elements (each one cm square) arranged in orderly progression from light to heavy. If the strip travels through the developer low density end first, the resulting characteristic curve will have somewhat higher toe, lower gamma, and more pronounced shoulder than if the same strip had been developed high end first.

Fig. 1 shows the effects obtained with four different area conditions and unidirectional development. First is a standard sensitometric exposure developed low end first; second is the same developed high end first. For curve *C* the exposure was confined to isolated $^1/_4$-in. circles. The last curve represents $^1/_4$-in. circles surrounded by very high densities. Although exposure and develop-

ment were identical in all cases we have four different characteristic curves for the same film. None of these truly depicts the H and D curve actually followed by the picture elements, for obviously the area conditions are not the same. In a typical picture the density elements are small and distributed in random fashion so that directional effect is less evident.

Our approach to the problem of avoiding the pitfalls of directional effect was to make sensitometric exposures of unusual form to approx-

FIG. 2. Gray-scale "mixed-density" test chart.

imate as closely as possible the neighborhood conditions prevailing in a normal picture. To meet the latter requirement we had to:

(*1*) Keep the individual picture elements as small as could be read on a standard densitometer;

(*2*) Avoid the regular progression of densities from low to high as in ordinary H and D exposures;

(*3*) Make the average density about the same as in an average picture;

(*4*) Avoid density extremes not ordinarily present in pictures.

We made a gray-scale chart of the desired form from pieces of printing paper flashed and developed to various densities, then photographed the chart with a 35-mm motion picture camera to obtain a negative suitable for print-through use. Fig. 2 shows a frame from this negative.

Great care was taken to avoid a series of progressively increasing

densities in the pattern. As a further precaution against systematic errors, in each frame there are two different elements with the same value of density so that it will be adjacent to a greater variety of other density areas. The picture area is divided into 16 elements.

We used a series of different exposures in making the original negatives such as to approximate the density scales appearing in a wide variety of picture negatives.

This "mixed-density" negative is used for print-through sensitometry in exactly the same manner as if it were a standard sensitometer strip. A few frames are spliced to the negative being duplicated, and the printed densities read at each stage of the operations.

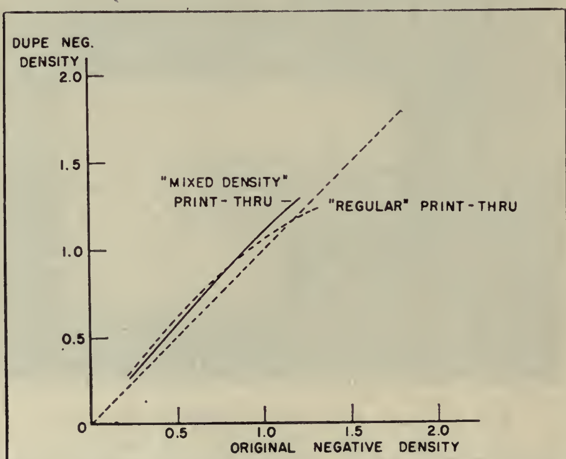

FIG. 3. Comparison of over-all density reproduction curves.

Results from the mixed-density exposures have been quite gratifying. We are able to obtain excellent correlation between sensitometric data and accuracy of reproduction as judged pictorially.

Fig. 3 illustrates how the mixed-density print-through results compare with the print-through from a standard-type sensitometer strip. The graph is a plot of dupe-negative density against density of the original negative. Perfect duplication would of course be represented by a straight line at a 45-deg angle. The average slope of the reproduction curve as indicated by the standard print-through strip is less than unity, while it is a little greater than unity according to the mixed-density curve. An actual picture carried through the duping process at the same time was judged slightly too contrasty according

to visual comparison of final prints. Note also that the considerable degree of curvature to the "regular" plot emphasizes the cumulative nature of errors caused by directional effects in the duping process. Alteration of the densities of the master positive H and D strip by directional effect introduces an exposure error when printing through the strip onto the dupe negative stock, which error is in addition to the directional effects in the dupe negative development itself. The final "regular" curve would indicate that good reproduction could not be obtained, a conclusion disproved by the fact that many laboratories

FIG. 4. Modified "mixed-density" test chart.

routinely produce duplicate prints almost indistinguishable from originals.

The mixed-density print-through system is likewise superior to the method of including original sensitometric exposures with the master positive and dupe negative developments. If these are developed low end first according to usual practice, the measured gammas of both are lower than is actually the case in the picture image. If development is adjusted to give a measured gamma product of unity, a picture made under these conditions will appear too hard.

Fig. 4 illustrates a mixed-density type of test negative modified to combine a picture with the series of small uniform densities. This modified test object was used in some recent work using duping tech-

niques to alter the contrast of the original rather than to obtain an accurate reproduction. It provides a sensitometric and a pictorial means of estimating contrast right in the same frame. As before, we had gratifying success in being able to predict picture contrast from sensitometric data.

We have found that the mixed-density technique spells the difference between success and failure in the application of sensitometry to the evaluation of dupes, by avoiding the errors which render the ordinary methods not wholly reliable for this use. To a processing laboratory it offers a sound quantitative basis for estimating quality of dupes and simplifies the diagnosis of unsatisfactory results. We do not pretend, on the other hand, that it would automatically lead to better quality than the artistic approach, for many laboratories already produce dupes of superlative quality; nor does the mixed-density offer any advantages over ordinary sensitometer exposures for maintaining processing levels once they have been established; it is needed for process evaluation purposes rather than in subsequent routine control.

Certain precautions must be observed in applying the mixed-density print-through method.

First, it is mandatory to have even illumination and uniform exposure in the printer. While this is a general requirement for first-class printing, small irregularities which are tolerable in pictures will lead to erratic results when a densitometer is used.

Second, if it is desired to set up printing and developing conditions with the criterion for success that the gamma product shall be unity, the densitometry must be beyond reproach. This means that the densitometer must measure a value of image density appropriate in both its spectral and geometric aspects to the actual conditions of use. Thus the original and dupe negatives should be measured in terms of printing density, while visual density should be used for describing the master positive and final print. If a contact-type printer is used, a diffuse density is the proper characteristic to measure. On the other hand, when duping is done on an optical printer the effective density is something intermediate between diffuse and specular density, and a densitometer which measures diffuse density would be inappropriate.

In conclusion, the mixed-density system of sensitometry is an illustration of a photographic fact learned through long experience;

namely, that to be reliable, test conditions must parallel closely the conditions of use. The departure in the form of the standard sensitometric exposure from the random density distribution in an actual picture leads to errors from head-and-tails development effects which are especially serious under duping conditions. Mixed-density exposures sidestep these directional errors by closely imitating the neighborhood density conditions in an average picture. By this method we secure a more accurate evaluation of film performance in the duping process than by conventional sensitometry.

RAPID TEST FOR FERRICYANIDE BLEACH EXHAUSTION*

L. E. VARDEN** AND E. G. SEARY**

Summary.—*Ferricyanide-type bleach solutions for removing silver in certain monopack color processes become relatively inefficient upon the accumulation of but a few per cent of ferrocyanide ion. A method is given for the rapid determination of the state of exhaustion of such bleach solutions, based on colorimetric estimation of the ferrocyanide concentration. The method is sufficiently reliable for processing control, and equipment common to motion picture laboratories is adaptable.*

Introduction.—In the processing of certain types of color film and color printing materials, it is necessary to remove a silver image to reveal the desired color image. For most monopack color processes a ferricyanide-type bleach is used in place of the stronger dichromate or permanganate bleach solutions recommended for black-and-white reversal processing. This is necessitated by the sensitivity of most dyes to strong oxidizing agents.

A typical silver bleach for monopack color materials consists of a soluble ferricyanide, a soluble halide, and suitable buffering compounds for maintaining *p*H constancy of the solution. The silver bleaching reaction in such a solution takes place in two steps. First, the ferricyanide ion attacks the silver image, oxidizing it to the relatively insoluble silver ferrocyanide, whereupon the lesser soluble silver halide is formed by reaction of the silver ion with the halide ion present in the solution. Thus,

$$4Ag + 4K_3Fe(CN)_6 \rightarrow Ag_4Fe(CN)_6 + 3K_4Fe(CN)_6 \qquad (1)$$

$$Ag_4Fe(CN)_6 + 4KBr \rightarrow K_4Fe(CN)_6 + 4AgBr. \qquad (2)$$

It will be noted that the ferrocyanide ion increases in concentration as the ferricyanide ion is depleted during exhaustion of the solution. The determination of the ferrocyanide concentration forms a desirable criterion of exhaustion since a small increase in ferrocyanide produces a disproportionately large decrease in bleaching rate.

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** Pavelle Color Incorporated, New York.

A simple, rapid and reliable colorimetric method for ferrocyanide determination has been found in the precipitation of the ferrocyanide with ferric chloride. The resultant ferric ferrocyanide is the intensely colored compound, Prussian blue.

$$3K_4Fe(CN)_6 + 4FeCl_3 \rightarrow Fe_4[Fe(CN_6)]_3 + 12KCl \quad (3)$$

As the bleach is used and the ferrocyanide ion concentration increases, the color produced by the addition of ferric chloride gradually changes from yellow to green. The change in color is sufficient to allow visual

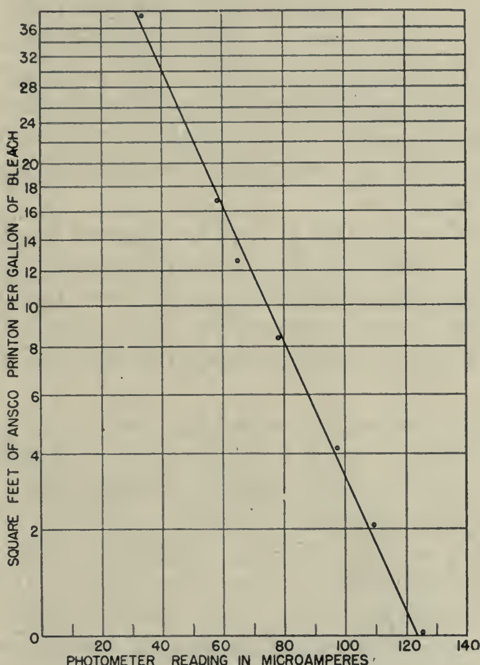

FIG. 1.

comparisons to be made against standard solutions or to permit direct absorption measurements with a simple photometer. The latter method is preferred since standard solutions are unstable.

Apparatus.—Since most processing laboratories have Eastman Kodak Argentometers for estimating silver content of fixing solutions, an attempt was made to adapt a Model *B* Argentometer,[1] equipped with its customary photronic cell and microammeter, as a photometer. It was found that the original rubber-ended Argentometer

cell is not suitable for use with ferricyanide solutions because the rubber is attacked. A fused glass cell, having a light path of 10 mm, was substituted with complete satisfaction.

Procedure.—In practice the bleach solution to be tested is diluted 100:1 with water to reduce the optical density to a measurable range. The addition of about one per cent of 6N HCl was found necessary with the bleach used in this work (Ansco *705*) in order to keep buffering material from precipitating. Approximately 25 cc of the diluted bleach are placed in the glass cell and the cell inserted in the Argentometer. The instrument is then balanced at 150 μa (zero on the silver scale). Two drops of 10 per cent $FeCl_3$ are now added and the solution stirred well. A reading of the microammeter is taken immediately, since the density of the solution slowly changes as the Prussian blue flocculates and eventually settles out. When first mixed, however, the test solution is perfectly clear and reproducible results are possible.

Experimental.—A series of freshly prepared bleaches of known exhaustion was tested by the above procedure. The decrease in light transmission of the test solutions was found to proceed in a regular manner with extent of exhaustion, as is shown in Fig. 1. Here the photocell current is plotted against the log of the area of material processed.

Conclusion.—The writers do not feel that a mere measure of the area of material processed is a valid indication of bleach exhaustion. Variation in exposure, and especially contamination, dilution, and aeration effects can affect the exhaustion markedly. For this reason a more positive measure of bleach exhaustion, such as the one outlined above, is preferrable for laboratory control. Although the data given are for a monopack color print material, the method is applicable for monopack taking and duplicating films where ferricyanide-type bleach baths are employed.

REFERENCE

[1] WEYERTS, W. J., AND HICKMAN, K. C. D.: "The Argentometer—An Apparatus for Testing for Silver in a Fixing Bath," *J. Soc. Mot. Pict. Eng.*, **XXV**, 4 (Oct. 1935), p. 335.

TONE CONTROL FOR RERECORDING*

C. O. SLYFIELD**

Summary.—*This paper covers the use of a tone track for automatic control of music and effects background in rerecording.*

During World War II those of us who were left at the studios were exceedingly busy working on government training films of a wide variety. It was necessary that these films be finished as quickly as possible as they were urgently needed for training the large number of men being taken into the military and naval services. Some of these films had no music or effects background behind the narration, but many of them had. This meant that the mixers must use footage counters, screen cues, or other means to indicate where the dialogue or narration started and stopped in order to fade or bring the background volume up in the proper places. Watching a footage counter or screen cues for long periods of time is very tedious and those of you who have experienced this know that it is very fatiguing.

Our first attempt to avoid this process was to use the RCA so-called "up-and-downer." This worked quite satisfactorily, but, when the narrator stopped for breath or made a slight pause, the background would rise in volume which was not desirable during these brief intervals. The timing constants of the rectifier and variable gain amplifier were adjusted to avoid this to a degree, but in doing so the fade and increase in volume time were not satisfactory.

In view of this difficulty, the idea was conceived of using a constant amplitude tone to control the gain of the amplifier through which the music and effects background was being transmitted. In other words, a tone would be used to control the gain of the amplifier instead of rectifying the dialogue signal itself as is done in the "up-and-downer." In our particular case, a frequency of 1000 cycles was used although other frequencies could be used just as well.

A great deal of experimental work was done on timing constants

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** Sound Department, Walt Disney Productions, Burbank, Calif.

which would give optimum results. The one which was picked as being most satisfactory for our service was that in which the fade took place in 15 frames and the increase back to normal level occurred in 30 frames. With these timing constants, the listener does not feel that the background is suddenly reduced for the dialogue or that the rise in volume at the end of the dialogue is so drastic as to be too noticeable. The music just seems to get out of the way without the feeling that the background is suddenly changed or notched to make way for the dialogue.

Some types of music and effects have to be dropped lower in volume than others in order to clear the dialogue. For this purpose a tone fader is provided on the rerecording console so that the amount of tone to be rectified is under control of the mixer at all times.

To prepare the control track, the dialogue track is set up on a dual counter with the second sprocket used for assembling the tone control

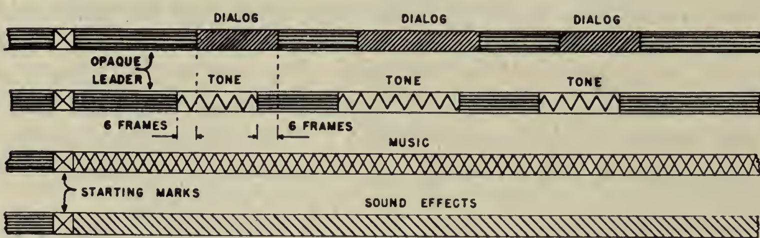

FIG. 1. Tone track arrangement.

track. A piece of 1000-cycle tone is spliced into this track so that it starts and stops with the dialogue. This is done for the entire reel. After the control track has been completed, it is advanced six frames and a "sync" mark applied. This, it will be seen from Fig. 1, makes the tone appear six frames ahead of the dialogue entrance. The tone also ends six frames before the end of the dialogue or narration. This six-frame advance allows $^1/_4$ sec anticipation before the entrance of the dialogue and causes the gain of the variable-gain amplifier through which the background is passing to be reduced sufficiently so that the first word of dialogue is not missed. The fade continues for 15 frames from the start of the tone and holds the background to a predetermined level until the tone ends—six frames before the finish of the dialogue or narration. At this time the rise in volume of the background begins and continues for 30 frames.

The block diagram of Fig. 1 shows the arrangement of the tone

track in relation to the other tracks which are being rerecorded. The block diagram, Fig. 2, shows how the rerecording system works with the tone track controlling the gain of the amplifier through which the background is being transmitted. It will be noted that the dialogue on sound head No. *1* is amplified through preamplifier No. *1* and the volume controlled by fader No. *1*. The dialogue signal is then impressed across one of the primary windings of transformer *T1*.

Music and effects are run on sound heads Nos. *3* and *4* and controlled by faders Nos. *3* and *4*, respectively. The combined outputs of these two tracks are sent through the variable-gain amplifier as shown. The tone track is run on sound head No. *2*, amplified by preamplifier No. *2* and the volume of the tone controlled by fader No. *2*. The tone output is then rectified by the tone rectifier as

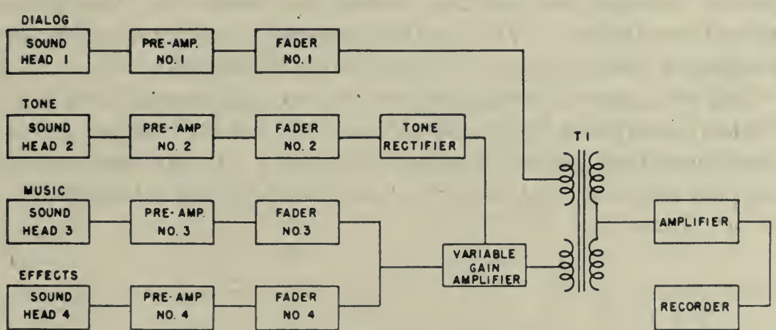

FIG. 2. Tone track rerecording setup.

shown in the diagram. The resulting negative direct-current potential is applied to the grids of a pair of push-pull *6K7* tubes in the variable-gain amplifier to reduce the gain of that device. The higher the value of tone, the greater will be the negative voltage applied to the grids of the *6K7* tubes thus controlling the volume of the variable-gain amplifier. The output of this amplifier is then impressed across the second primary coil of transformer *T1*. The combined outputs of the dialogue and the variable-gain amplifier in the secondary winding of this transformer are transmitted to the recording amplifier and then to the recorder itself. It will be noted that the volume of the dialogue is controlled manually, but the volume of the music and effects is controlled both manually and by means of the rectified tone which actuates the variable-gain amplifier through which these elements are passing.

The 1000-cycle sections can be removed from the tone track after the rerecording has been completed, spliced together and used over and over again.

Other methods have been considered for accomplishing the same results as are obtained with the tone control track, but these have been discarded for various reasons. One method suggested was the use of a notch on the edge of the dialogue track which would either operate a tone or some other device for controlling the volume of the amplifier through which the background was being transmitted. This system could be used quite easily, but there is always the problem of making changes after the rerecording tracks have been prepared. It is somewhat difficult to change the position of a notch, whereas the tone track can be changed quite readily by simply using more or less tone or changing the position of the tone which has already been spliced into the reel. The tone track, of course, requires no blooping so changes can be made with speed and little difficulty.

The tone control track system works remarkably well and is particularly adapted for dialogue pictures which have more or less of a continuous background of music and effects. It has been used for the past two years and has proved itself to be highly satisfactory.

POSTWAR TEST EQUIPMENT FOR THEATER SERVICING*

EDWARD STANKO** AND PAUL V. SMITH**

Summary.—*This article outlines the underlying reasons for the need of new and modern test equipment for properly servicing theatrical sound reproducing equipment with the minimum expenditure of time. A detailed description is given of a modern test kit designed to fill this need, with photographs of the kit and schematic diagrams of its special instruments.*

Early in 1946, several months after cessation of the war, new test equipment for servicing theater installations was designed and is now in production. With the advent of war in 1941, civilian test and measuring equipment production was stopped. By the end of the war the cumulative wear and tear on these instruments, plus emergency repair expedients, made it necessary to replace the major portion of the existing equipment.

Careful studies of the requirements of postwar test equipment indicated the advisability of incorporating certain special test instruments which would expedite field work, aid in obtaining accuracy of measurement, speed the identification of defective components, and permit the equipment to be of maximum usefulness under all possible field conditions. These special instruments for field work will be explained in detail later in this paper.

The continual improvement of motion picture sound equipment, with its increased fidelity, imposes more rigorous requirements on the field test equipment necessary to maintain its circuits and its optical and mechanical parts in their original condition and adjustment. Also, this new field test equipment must be easily portable if it is to be of maximum usefulness. Fortunately, there are now available miniature tubes and other parts, developed during the war, which contribute materially to this requirement.

During the war, instrument research has been greatly accelerated. The advent of alnico magnets has made possible stronger magnetic

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** RCA Service Company, Inc., Camden, N. J.

fields, more rugged moving systems, and higher torque springs, all of which contribute to accuracy, ruggedness, and reliability, as well as lighter weight. Miniature tubes have been developed which can stand the shock of being fired from a gun in an antiaircraft shell. Tubes incorporating these developments will withstand the shocks incident to use in portable equipment much better than prewar tubes.

With these things in mind, a new 1946 model test kit has been designed, consisting of a varnished, reinforced fiber case, with compartments for the various instruments. When the lid is closed, these instruments are held firmly in place. The case is 19 in. long, $7^1/_2$ in. deep, and 14 in. high when its carrying handle is folded. Including

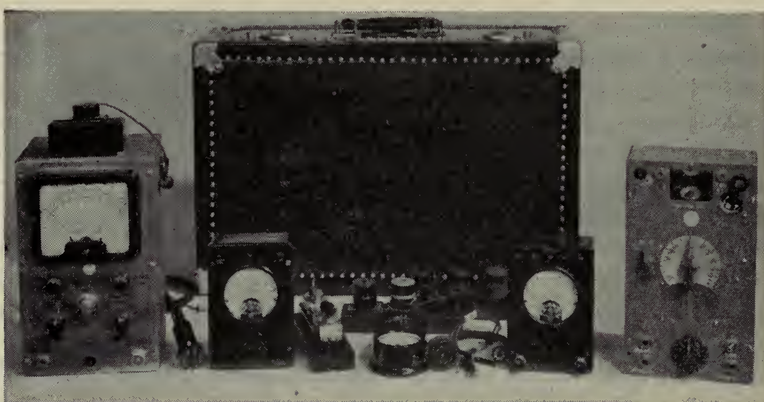

FIG. 1. Theater servicing test equipment and carrying case.

all instruments, it weighs 35 lb. The case contains an RCA VoltOhmyst especially designed to operate on self-contained batteries instead of on alternating current, which was required for previous models. A neon pilot lamp is connected to the batteries through a resister-capacitor network and the selector switch, and flashes repeatedly when the batteries are in use. This effectively attracts attention, and consumes only a few microamperes of battery current.

The VoltOhmyst can be used to measure direct-current voltages from 0.10 v to 1000 v over six ranges, with an error of less than 2 per cent of full scale on each range.

Measuring is accomplished by a two-tube, balanced-bridge circuit which permits a constant, high input resistance of 11 megohms on all ranges, and protects the instrument moving system from burn-out

should excessive voltage be applied. Because the normally negative lead is grounded to the instrument case, a reversing switch is provided to allow measurement where the ungrounded side of a voltage source is negative. The high-side input probe incorporates a one-megohm isolating resister, thus permitting measurements to be made in signal-carrying circuits without adding a serious lead capacitance which might introduce excessive circuit loading or distortion.

The resistance meter also utilizes the bridge circuit and can be used to measure resistances from 0.1 ohm to 1000 megohms over six ranges. A 3-v, heavy-duty battery furnishes voltage for all ranges. The voltage applied to the part being measured does not exceed, and is

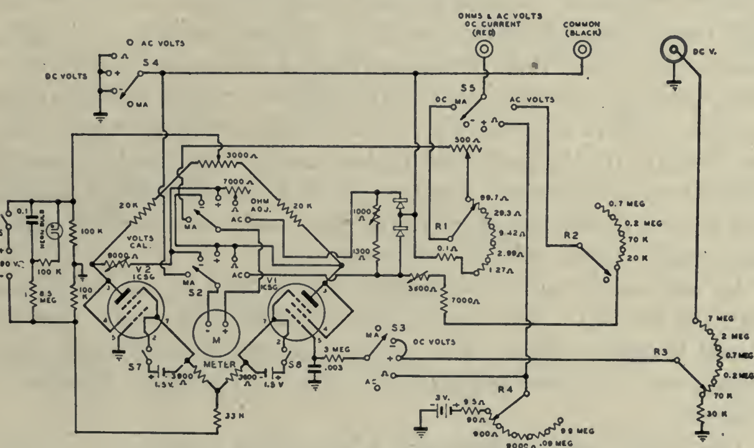

FIG. 2. Circuit diagram of special VoltOhmyst.

usually much less than, 3 v; this is of advantage when small lamps, alloy-steel core transformers, and other items susceptible to damage by excess current are to be measured.

Because the bridge circuit isolates the meter moving system from the measuring circuit, accidental connection of the ohmmeter leads to a live circuit or to a charged capacitor will not result in instrument burn-out. The resistances themselves are rugged enough to withstand a large momentary surge or overload without damage.

The special VoltOhmyst can be used to measure alternating-current voltages of commercial and low audio-frequencies from one volt to 1000 v, over five ranges. When so used, it becomes a conventional copper-oxide-rectifier voltmeter with a resistance of 1000 ohms per volt. No series resistor is used in the alternating-current leads.

The measuring circuit is isolated from the case ground, when alternating voltage is measured.

This special VoltOhmyst also measures direct current from 100 μa to 5 amp, over six ranges, with accuracy of ± 2 per cent of full scale, by the use of shunts on the meter moving system. The measuring circuit is isolated from the case ground when measuring current.

A standard socket selector kit with a complete complement of adaptors and sockets, including those for the new seven-prong miniature tubes, is furnished for analysis of tube circuits. Two pin jacks are installed in the top of the special VoltOhmyst described above; these provide for mounting the socket selector block on the top surface of the VoltOhmyst. Connections are readily made to the socket jacks with the standard VoltOhmyst leads. When the sockets and adaptors are not in use, their prongs are pushed into rubber-lined dummy sockets in three wooden carrier blocks which are then slid into corresponding slots in the carrying case. The soft rubber dummy socket hole linings grip the prongs firmly but easily. This facilitates accessibility of the sockets and adapters, and helps prevent loss or damage. The general knowledge of the use of these socket selector kits renders any detailed explanation herein unnecessary.

An alternating-current voltmeter and decibel meter is furnished with the test kit. This instrument is smaller and lighter than the special VoltOhmyst and, since it can be used for alternating-current voltage measurements from 0.25 to 150 v, may serve as a pocket instrument.

This decibel meter is necessary when testing personnel are making frequency response runs, transmission tests, gain or loss tests, amplifier overload checks, or similar system measurements. Instruction sheets are furnished with this instrument to enable the user to correct the readings should the instrument be used on lines of impedances differing from that for which the instrument was calibrated, or to convert the readings to those corresponding to a different zero level, or both. This voltmeter includes a series blocking capacitor which is to be used when the instrument is connected to a circuit carrying both direct and alternating current.

An alternating- or direct-current ammeter also is supplied. This instrument can be used to measure currents of from 0.1 to 15 amp, either alternating or direct current, over two ranges. In addition, a pair of terminals is provided to connect to the leads from any standard 50-millivolt drop shunt, for measuring higher values of direct current.

The latter two instruments are held in place in the case by wooden blocks, and when the cover is closed, cannot shift or rattle around.

A 150-amp, 50-millivolt drop shunt is also furnished, which can be connected to the ammeter to enable measurements of direct current up to 150 amp. This is necessary when adjusting arc lamp rectifiers, checking arc lamp ammeters, *etc.* This shunt is permanently mounted on a wood block which slides into a slot in the case adjoining those on which the socket selector adapters are mounted.

The Triatic Signal Tracer, which is a standard unit in the kit, was especially developed to fill a long-felt need for a universal tester. It will measure capacitors of values between 10 micromicrofarads and

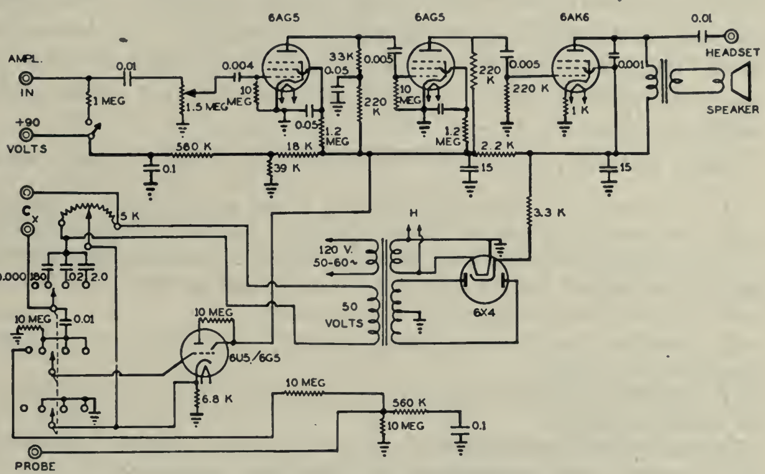

FIG. 3. Circuit diagram of Triatic tester.

80 microfarads, over three ranges, with an accuracy of 5 per cent or better. The signal tracer will also indicate whether the capacitor being tested has low or high shunt resistance. Bridge balance is indicated directly by a *6U5/6G5* electron-ray indicator tube. The use of this tube eliminates delicate instruments or bothersome headphones, and the indication is not confused by any harmonics that may be present in the supply voltage.

It incorporates a three-tube, high-gain audio-frequency amplifier and a 3-in. PM speaker. The amplifier has approximately 100-db gain and a power output of 200 milliwatts. Its high impedance input (1.5 megohm) can be connected directly to a signal-carrying circuit without appreciably disturbing the signal. The volume control is in

the input circuit; therefore, a high-level signal at the amplifier input can be reduced sufficiently to prevent overloading any part of the amplifier. A series blocking capacitor in the input circuit prevents any direct-current voltage from reaching the volume control or the grid of the first tube; the input connection can, therefore, be attached directly to the amplifier plate circuit. An output jack, capacitively coupled to the plate of the output tube, facilitates the use of headphones if desired. Power is supplied by a built-in power supply operating from the 120-v, 60-cycle alternating-current line.

A jack on the front panel is connected, through a resistor-capacitor filter, to the integral power supply, and will supply anode voltage to one or two photocells. This voltage may be connected, by the simple throwing of a toggle switch, through a one-megohm coupling resistor to the amplifier input jack. This connection permits the amplifier to operate directly from a photocell without any other electrical connections whatever.

These features permit the use of this device for many tests, such as:

(*1*) Focusing optical systems, adjusting lateral guide rollers, or balancing push-pull photocells on one sound head while the other is in normal operation;

(*2*) Checking one sound head for proper operation, normal photocell output quality, film, exciter lamp, and photocell defects, hum or vibration pickup, *etc.*, while the other sound head is in normal operation;

(*3*) Stage-by-stage tracing to locate sources of noise, distortion, intermittent operation, or low gain;

(*4*) Testing auxiliary devices, such as microphones, phonograph pickups, *etc.* for normal operation;

(*5*) An emergency substitute for the normal photocell anode supply, and the first stages of theater sound systems, in which failure has occurred;

(*6*) Talk-back from stage to projection room when installing equipment (when used with a microphone);

(*7*) In conjunction with a photocell, to find out whether room illumination supply is direct current or alternating current. (With a photocell and test lamp, to determine whether an unknown power source is direct or alternating current.) If alternating current, hum will be heard from the loudspeaker; if direct current, no hum will be heard, but clicks may be produced by interrupting the light which falls on the photoelectric cell.

The Triatic Signal Tracer also includes a circuit probe tester incorporating a resistor-capacitor circuit and the electron-ray tube *6U5/6G5*. This circuit provides a means of rapidly checking an amplifier or similar circuit to determine the approximate voltages present, their polarity, and whether they are direct or alternating. Only one range is needed, which is not subject to burnout or damage

on voltages ordinarily found in an audio-frequency amplifier. This range extends approximately from 2 v to 500 v. Direct-current voltages are indicated by the opening or closing of the electron-ray tube shadow, depending on polarity; the voltage is estimated by noting the time taken (after the probe has been removed from the circuit being tested) for the resistor-capacitor circuit to discharge enough to allow the electron-ray tube shadow to return to its normal position. This is accurate enough for rapidly checking circuits in case of trouble, when it is merely necessary to determine whether or not the voltage present is somewhere near its normal magnitude.

The alternating-voltage indication is a blurring of the edges of the electron-ray tube shadow, the result of the rapid opening and closing produced by the applied alternating voltage. Since alternating voltage cannot charge up resistor-capacitor circuits to any permanent value, voltages are indicated by the width of the blurred area.

All necessary cables, plugs, and cords are furnished with this equipment. These are placed in space provided in the bottom of the cabinet. In addition, a bracket is provided on the back of the special VoltOhmyst for carrying its own plug leads.

Additional space is available for other small instruments should future developments require their use in addition to those now provided.

The large number of varied and comprehensive tests possible with this equipment will allow the theater service engineer to keep equipment running at its optimum, and to locate any trouble which may develop. The service of a competent engineer equipped with modern test equipment is the best possible guarantee of continuous high-quality sound reproduction.

ZOOM LENS FOR MOTION PICTURE CAMERAS WITH SINGLE-BARREL LINEAR MOVEMENT*

FRANK G. BACK**

Summary.—*Previous varifocal lenses used two or three movable components which had to be shifted against each other. This movement was necessarily nonlinear and therefore had to be achieved by nonlinear cams. This presented many mechanical difficulties and it was nearly impossible to obtain an accurately focused image over the entire range. In addition, the shifting of the movable components against each other caused numerous aberrations.*

The new varifocal lens has only one movable barrel, and the compensation of the image movement is achieved solely by optical, and not by mechanical means. Therefore, the lens gives a well-focused image sufficiently free from aberrations at all positions.

In order to avoid monotony or accentuate details, it is desirable in many instances to start a motion picture scene with a close-up and end it with a long shot, or vice versa, in such a way that the transition is not effected abruptly but that the object seems gradually to come closer or go farther away on the screen. Such an effect is achieved in three different ways.

First: The camera itself moves toward or recedes from the object. This method is complicated and requires the teamwork of several highly skilled camera operators in order to "follow focus," get a smooth movement, and keep the target in proper range and frame. At the same time, this method often necessitates complicated and awkward installations and is mainly used in studio work.

Second: The shots are taken from a stationary camera with a wide-angle lens, and the zoom effect is achieved later by means of an optical printer. This method is rarely used because steady movements over a large number of frames without change in exposure are difficult to achieve. Moreover, if the detail to be shown is not in the center of the frame, steady movements are almost impossible to accomplish.

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* Presented May 8, 1946, at the Technical Conference in New York.

** M.E., Sc.D., Research and Development Laboratory, 381 Fourth Ave., New York.

Third: A stationary camera is used in conjunction with a varifocal lens, a so-called "zoom lens." The requirements for a zoom lens are as follows: Good definition over the entire range of focus; smooth operation; no change in exposure during the zooming; and foolproof performance.

The zoom lenses developed to date do not meet the above-described requirements because of their rather complicated mechanical design, and for this reason they have not been accepted in spite of their undeniable advantages. For each of the focal lengths required the

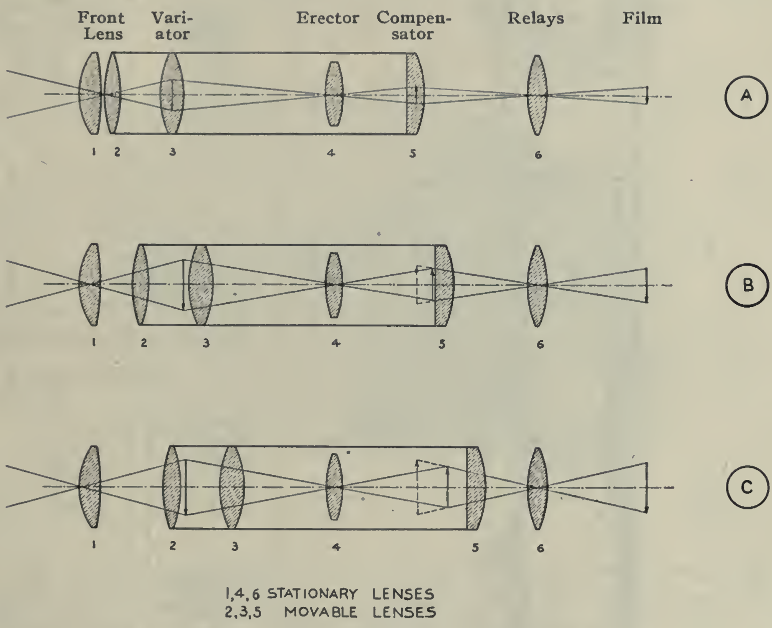

FIG. 1. Optical principle of Zoomar lens.

designer computed the exact position of each component, trying, of course, to keep the number of movable elements as small as possible. The shifting of the movable elements was then plotted against the different focal lengths. The resulting graph was taken as the basis for a cam movement needed to displace the movable lens elements with relation to each other. The disadvantage of such a lens lay mainly in the fact that it was nearly impossible to obtain an accurately focused image over the whole focal range because of necessary tolerances in manufacturing. Only some points gave satisfactory resolu-

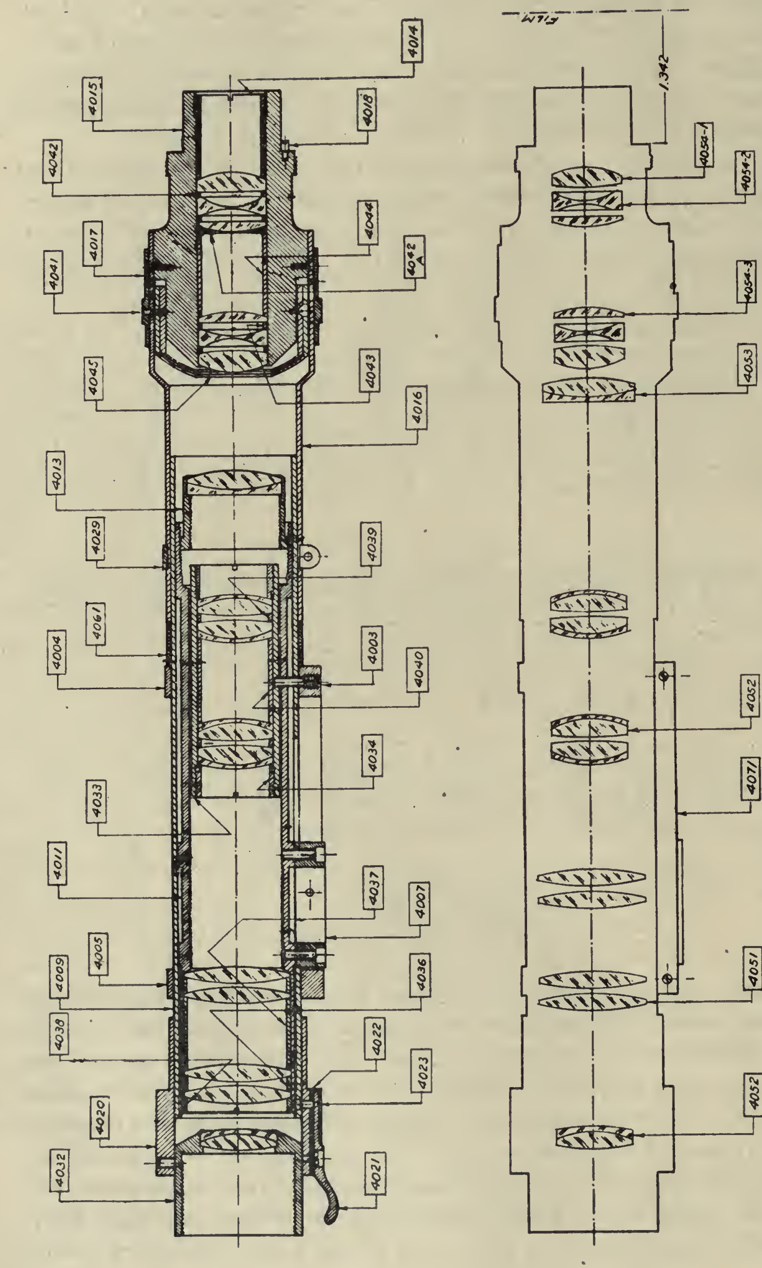

FIG. 2. Cross section of Zoomar lens: top, wide-angle position; bottom, tele-photo position.

tion, while other points were definitely out of focus even if these lens systems had been fully corrected for the seven aberrations. This in itself was impossible to achieve with a system of the above-described type.

An even graver disadvantage of these lenses lay in the fact that although a skilled craftsman could produce a lens system of such close tolerances, it is inevitable that wear, even in the most accurately designed and manufactured mechanism, produces a certain play sufficient to throw the system out of focus. Therefore, nearly all of the varifocal lenses marketed so far became unusable after a relatively short time.

FIG. 3. Zoomar mounted on Ciné Kodak Special.

We have designed and developed a new zoom lens where the chief goal was simplicity, as far as the mechanical movements were concerned, with assurance that the picture quality would not suffer from normal wear. We have been able to find certain equations and optical relations which permit full compensation with strictly linear displacements of optical components. The result is a varifocal lens with a single barrel movement. Any cams, gears, or nonlinear helices are completely eliminated and the compensation is achieved by optical means.

There are only two groups of elements in the zoom lens; namely, stationary elements and coupled movable elements. The stationary elements are mechanically connected by the housing; the coupled movable elements are mounted in a common barrel. Movement of

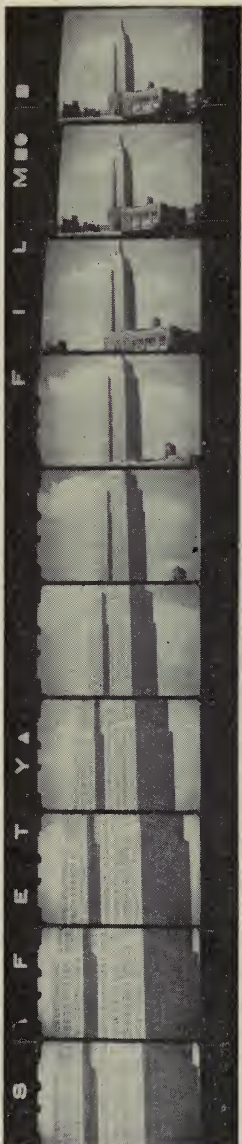

FIG. 4. Compound zoom shot of Empire State Building.

the barrel to any position in the housing yields a stationary image of varying size.

Fig. 1 shows a simplified schematic view of our lens arrangement in three positions. Position *A* is the wide-angle position; position *B* the medium position; and position *C* the telephoto position.

Elements *1*, *4*, and *6* are the stationary group. Elements *2*, *3*, and *5* are the movable group. The stationary elements do not change their position within the lens-housing; elements *2*, *3*, and *5* are moved simultaneously. The effect is a picture of variable size but stationary as far as displacement along the lens axis is concerned.

Although Fig. 1 shows the principle of the new zoom lens, each lens element shown represents a group of lens components in itself, because every one of these lenses has to be corrected for chromatic and spherical aberration and for astigmatism. Coma and distortion are eliminated by the concerted interplay of all groups.

As already stated, this arrangement compensates for any displacements of image in the film plane, so that the image remains stationary in spite of changing its size. Fig. 2 shows a cross section of the entire zoom lens.

Fig. 3 shows the zoom lens with a coupled Zoom-Viewfinder mounted on a Ciné Kodak Special.

Fig. 4 shows a zoom shot taken with the lens to illustrate its focal range.

In closing, I wish to thank A. L. Varges, of *News of the Day*, and W. K. Jacobi, of the Long Island Optical Company, for their valuable cooperation. Also, I wish to express my thanks to H. Lowen, our chief mathematician, for the untiring and devoted services he rendered in the course of this research work.

A NEW SELSYN INTERLOCK SELECTION SYSTEM*

DANIEL J. BLOOMBERG** AND W. O. WATSON**

Summary.—*This paper describes a new type of Selsyn interlock selector switch wherein six-pole, five-position rotary switches utilize a combination operating motion. Position selection is obtained by rotary motion and contacting by plunger motion.*

Selsyn motor and distributor systems are universally used in motion picture production for the synchronizing of the sound, camera, and projection motor operation. The involved multiple patching methods generally practiced, using a patch plug and cable connector system for the selection and interlocking of motor and distributor busses, is somewhat cumbersome.

The interlock selection system described in this paper eliminates cable patching and provides a simple, convenient method of interlock motor and distributor selection.

The design of a switching method, wherein only two distributor busses are used, is comparatively easy. However, where three or more distributors are used, then the problem arises of being able to select any distributor without contacting a bus which is in operation. The solution to this problem was the primary incentive to the Republic Sound Department in designing the multiple interlock switch.

Fig. 1, a block diagram, and Fig. 2, a schematic diagram, depict a typical Selsyn system. In this arrangement there are three distributors and five interlock motors. To connect each motor to a distributor bus it has been necessary in the past to connect a large 6-pin plug into the de-energized bus at each machine or at a central patching panel in or near the machine room. The new interlock selection system provides a switch for each Selsyn motor, and in order to connect a motor to any distributor at rest, it is necessary only to rotate the switch to a designated position and depress the knob.

In Fig. 3 there are three switch units mounted rigidly by four spacer rods. Construction of the base and contact arms in the closed

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* Presented May 18, 1945, at the Technical Conference in Hollywood.

** Republic Productions, Inc., North Hollywood, Calif.

or operating position may be seen in the cut-away cross section. Each switch unit consists of ten "micro-action" type switches mounted in a radial form on an insulated base. Two sets of contacts on each

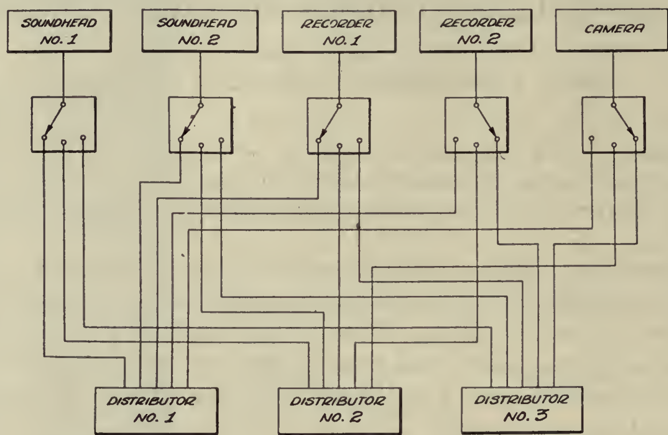

FIG. 1. Typical Selsyn installation.

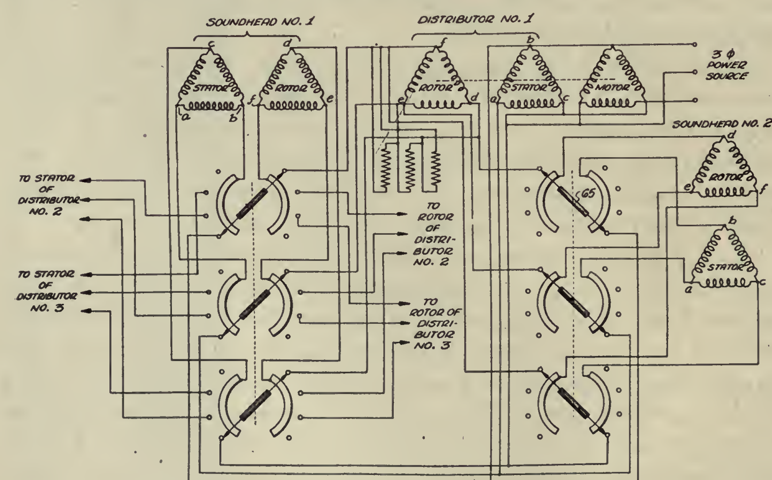

FIG. 2. Typical Selsyn switching circuit.

switch unit are actuated by means of two plungers spaced 180 deg apart on the associated actuating disk. The actuating disks are mechanically connected together through their centers by extruded rod as shown. These disks are not rigid, but float on the connecting rod

and are held in position by the spring *174*, Fig. 3. This spring acts as a cushion and is designed to equalize the pressure required to operate each set of switch contacts. A radial detent, spaced at 21 deg, positions the actuating pin disks.

The switch is operated by depressing the trigger *144* and pulling out the knob *141* retracting the actuating pins from the contact position. The switch may then be rotated to the required position and pressed

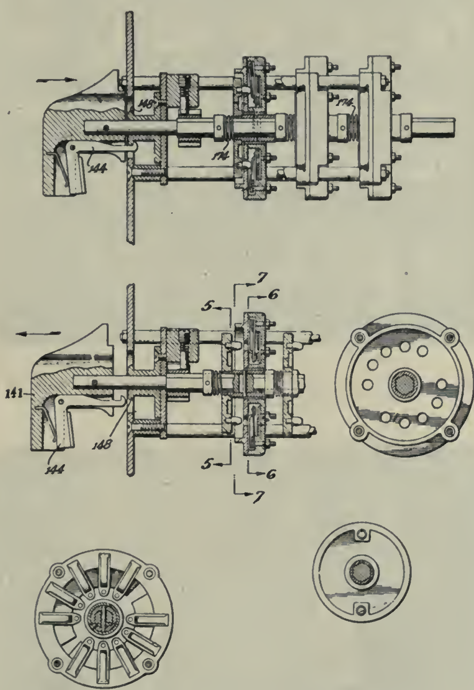

FIG. 3. The new interlock selection switch.

in until the trigger latch engages the circular sear at *148*. This motion moves the actuating disks and plungers into contact with the micro-type switches, snapping them into the closed circuit position. The plungers also serve as indexing pins preventing accidental movement of the knob. Thus the switch may be rotated through any operating bus position without actuating the micro-type switch, and does not make contact until the knob is pressed home at the selected bus.

This system has been installed in the Republic Studio Sound Department and the main Selsyn distribution panel has 30 switches con-

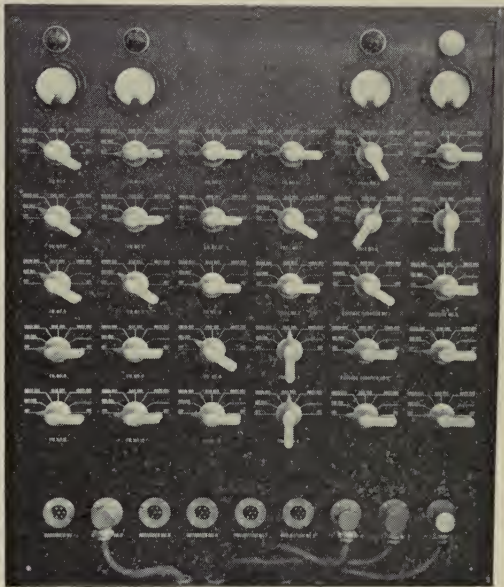

FIG. 4. Main Selsyn distribution panel installed at Republic Studios.

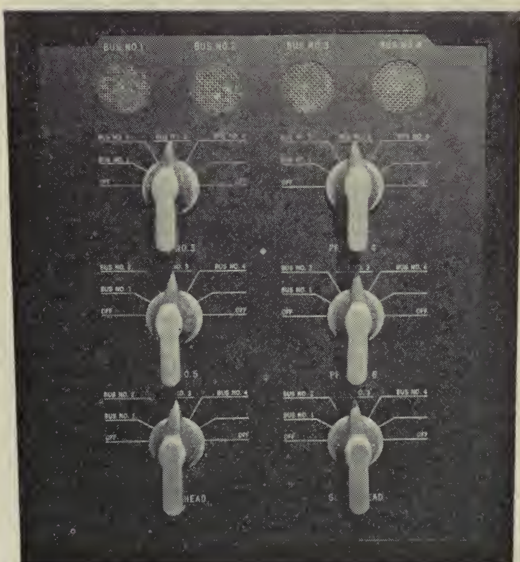

FIG. 5. Projection room control panel.

trolling 30 interlock motors and four distributors as shown in Fig. 4. The projection room in stage 12 has a similar panel with six switches and is shown in Fig. 5. This system has been in operation for over a year and has proved highly satisfactory.

The advantages of the new interlock selection system are:

(*1*) Simplified operation results in reduction of time required to set up the system,

(*2*) Ease of transferring any motor to another distributor, after setups have been made,

(*3*) Distribution panel may be installed in a more convenient central location than the patch-type panel because of greatly reduced space requirements (30 switches in a panel 30 in. × 30 in. × 9 in. deep),

(*4*) Improved appearance of panel with elimination of patch cables.

A PROCESSING CONTROL SENSITOMETER*

GERALD A. JOHNSON**

Summary.—*A sensitometer which gives an intensity-scale exposure has been developed as an aid to the control of photographic processing conditions. The illumination is modulated by a photographic step tablet of 21 steps in which the exposure increases by increments of $\sqrt{2}$. Positive films are exposed to an incandescent lamp operating at 2850 K, while with negative films, dyed gelatin filters are inserted in the optical system to approximate sunlight quality. A pendulum mechanism furnishes a $^1/_{10}$-sec exposure time for positive and negative films. Where longer exposure times are needed, as, for example, with photographic papers, an additional manual shutter is provided. The instrument gives highly reproducible results for process control but is not calibrated in absolute units.*

As an aid in controlling photographic processing conditions, a small, portable sensitometer was developed during the war for the Army, Navy, and Marine Corps. It was called the Processing Control Sensitometer and proved to be so useful that an improved model has been built. A picture of it is shown in Fig. 1.

The instrument, built to utilize a voltage of 110 ac but capable of operation on other voltages, with minor alterations, provides a rapid and convenient means of making reproducible sensitometric exposures. Film strips from control emulsions, exposed with the sensitometer, can be compared with previously exposed and processed strips from the same control emulsions. In this way, speed and contrast trends can be followed closely, and accurate control of the uniformity of developing conditions can be maintained. The sensitometer can also be used to test relative speeds, contrasts, and other sensitometric properties of various films.

In the last 50 years many sensitometers have been developed as aids in investigating the characteristics of photographic films and papers. Mees[1] has summarized this progress. All sensitometers are classified either as intensity-scale or time-scale instruments. An example of the latter class is the Eastman IIB Sensitometer,[2] which is

* Presented May 6, 1946, at the Technical Conference in New York.

** Eastman Kodak Company, Rochester, N. Y.

FIG. 1. Processing control sensitometer.

a popular precision instrument giving a constant-intensity, variable-time exposure. The former group, intensity-scale sensitometers, which are more common, furnishes constant-time, variable-intensity exposure with the aid of devices like absorbing tablets. Accurate step tablets and wedges sold by photographic manufacturers have made it possible to construct simple and efficient instruments of this

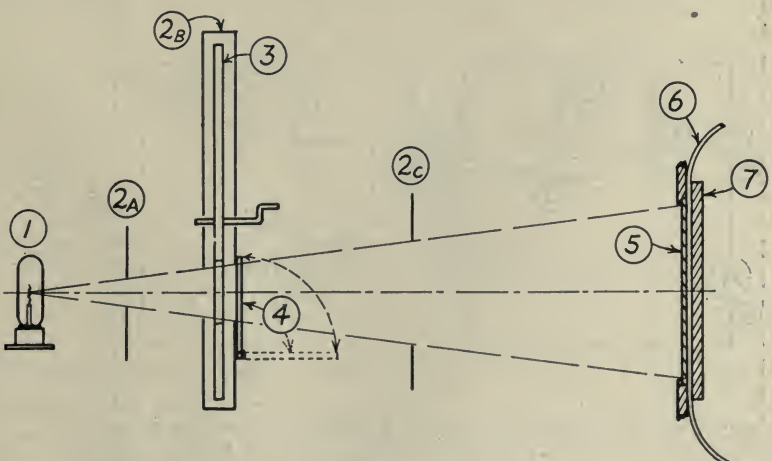

FIG. 2. Optical system of processing control sensitometer.

FIG. 3. Step tablet, ammeter, and control knobs of processing control sensitometer.

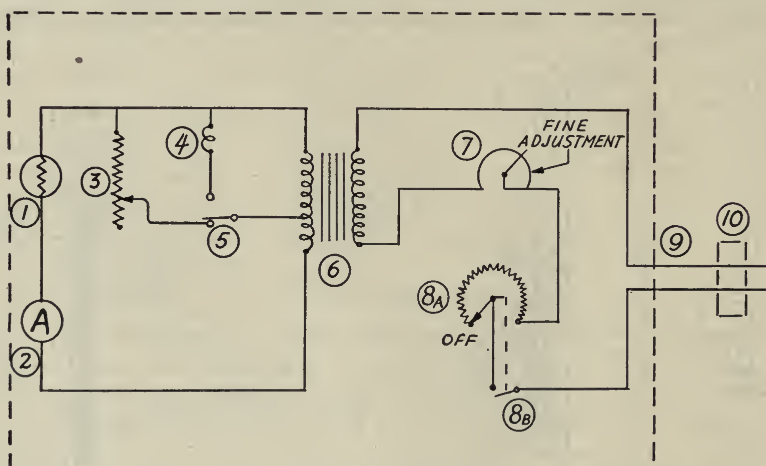

FIG. 4. Electrical wiring diagram of processing control sensitometer.

type. Their precision is satisfactory for controlling photographic processing and for general sensitometry, but it is not good enough for primary instruments in a sensitometric laboratory. The Processing Control Sensitometer is of this class.

FIG. 5. Typical exposed and processed film strip.

A schematic drawing of the optical system is shown in Fig. 2, where *1* is an incandescent light source, and *2A*, *2B*, and *2C* are light baffles. A pendulum disk shutter *3* is used as a timing device. No. *4* indicates the filter holder or manual shutter. No. *5* is a light modulator con-

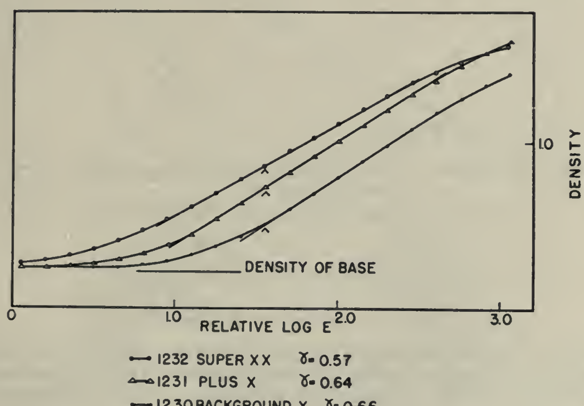

FIG. 6. Characteristic curves for motion picture negative films exposed with the processing control sensitometer. Film developed in Kodak *SD-21* at 65 F; processing control sensitometer negative setup.

sisting of a photographic step tablet, *6* is the film strip to be exposed, and *7* the film cover door.

As shown in Fig. 1, the lamp house containing a 10-v, 7.5-amp photocell exciter lamp is at the back of the sensitometer. Directly in front of it is the pendulum timing mechanism, which must be level

to operate properly. Leveling of the timing mechanism is accomplished by rotating thumbscrews attached to the feet until the bubbles of the two crossed levels are centered. By turning the crank clockwise the pendulum is prepositioned on the releasing latch, which when tripped allows the pendulum to swing through about 260 deg. A 60-deg opening in the pendulum disk permits the light to pass for $^1/_{10}$ sec. At the end of its swing the pendulum is caught, ready to be prepositioned for the next exposure.

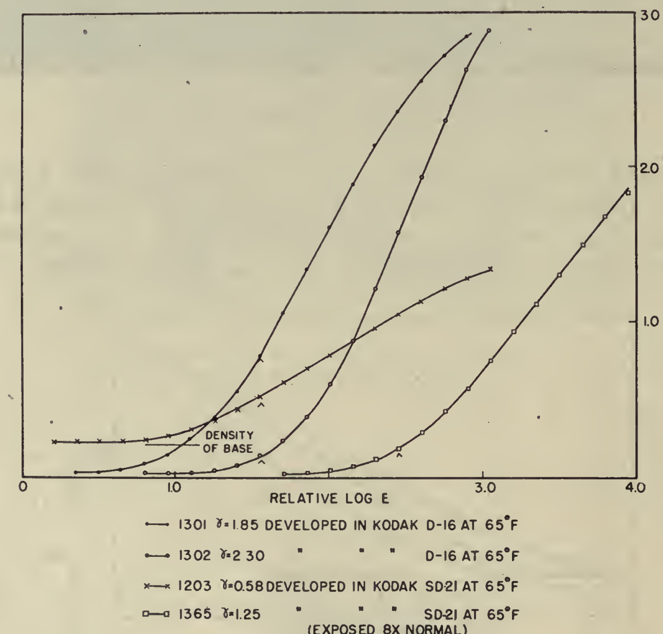

Fig. 7. Characteristic curves for motion picture positive, master positive, and duplicate negative films exposed with the processing control sensitometer; processing control sensitometer positive setup.

When the arrow on the filter control knob at the side is turned to the *P* (positive) position, unfiltered light of 2850 K illuminates the film, while with the knob in the *N* (negative) position, a bluish Wratten *78AA* filter and a 0.60 neutral density filter are inserted in the light beam to give approximate sunlight quality illumination. Film strips to be exposed are placed inside the film cover door (Fig. 3) and against the step tablet, which has 21 steps with a gradient of $\sqrt{2}$. The rheostat knob *A* turns on the exposing light and acts as a coarse adjust-

ment; rheostat knob *B* is for fine control. The ammeter is illuminated by green light when the light switch button near the levels is pressed. The lamp is operated at approximately 6.5 amp to give 2850 K, and the needle deflection may be watched through the scale window. Fluctuations in line voltage are reduced by the use of a voltage regulator. The electrical wiring diagram of the transformer, rheostats, and lamps is shown in Fig. 4. A list of these electrical parts for the instrument is given in the Appendix.

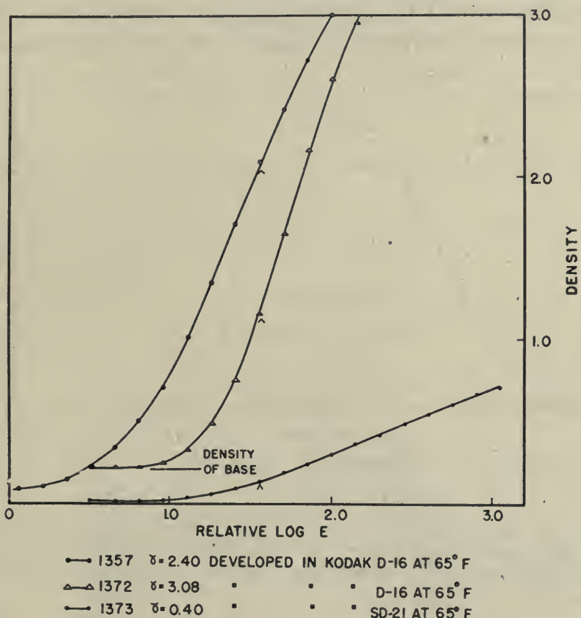

FIG. 8. Characteristic curves for motion picture sound recording films exposed with the processing control sensitometer; processing control sensitometer positive setup.

A reproduction of a typical exposed and processed strip is shown in Fig. 5. The exposure area is $^7/_8$ in. by $4^1/_4$ in., each step being 5 mm by $^7/_8$ in. Strips exposed in this manner may be compared on an illuminator to note differences or, if a densitometer is available, the densities of the exposed samples may be plotted against the densities of the step tablet. Fig. 6 presents typical characteristic curves for three motion picture negative films exposed on the processing control sensitometer to sunlight illumination for $^1/_{10}$ sec.

Motion picture positive films, as well as master positive and duplicate negative film, exposed on the same instrument to 2850 K radiation for $^1/_{10}$ sec, give characteristic curves shown in Fig. 7. Included in this illustration are curves for Release Positive Film, type *1301;* Fine Grain Release Positive Film, type *1302;* Fine Grain Duplicating Positive Film, type *1365;* and Fine Grain Panchromatic Duplicating Film, type *1203*. With the slower emulsions, it is sometimes necessary to give multiple exposures; for example, with type *1365*, an exposure of eight times normal is required.

Characteristic curves for motion picture sound recording films, types *1357*, *1372*, and *1373*, are shown in Fig. 8. Samples of these

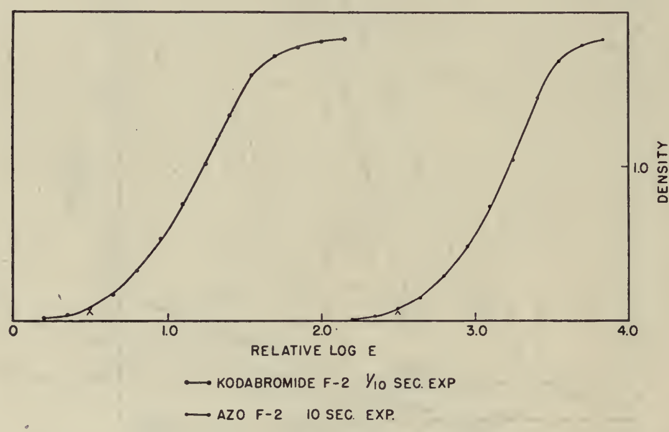

Fig. 9. Characteristic curves for photographic papers exposed with the processing control sensitometer. Film developed in Kodak *D72* at 65 F; processing control sensitometer positive setup.

films were exposed under the same conditions used for the positive films.

Professional and commercial sheet films may also be exposed to either sunlight or tungsten illumination by inserting an edge or a corner of the sheet under the film cover door and setting the filter control knob in the desired position.

Since photographic papers are much slower in speed, it is necessary to use longer exposure times when exposing such materials. This is accomplished by removing the filter from its holder and inserting a sheet of metal or cardboard, which may be used as a manual shutter for exposure times longer than 10 sec. Characteristic curves for

Kodabromide *F-2* and Azo *F-2* papers exposed with this sensitometer appear in Fig. 9.

Since the intensity of the lamp changes with age and the lamp is uncalibrated, an additional lamp is used as a reference standard or monitor. After both lamps have been seasoned by burning for at least 2 hr, periodic checks of the exposing lamp are made against the monitor. In this way any drifts caused by the exposing light can be detected. When the exposing light shows an appreciable drift, the monitor should replace it, and a new monitor should be selected.

With reasonable care, the processing control sensitomer will give highly reproducible results both for controlling processing conditions and for making relative sensitometric film tests.

REFERENCES

[1] MEES, C. E. K.: "The Theory of the Photographic Process," Macmillan Co. (New York), 1942; Chap. XVI, p. 587.

[2] JONES, L. A.: "A Motion Picture Laboratory Sensitometer," *J. Soc. Mot. Pict. Eng.*, **17**, 4 (Oct. 1931), p. 536.

Appendix

Electrical Parts List

Index No.	Description
1	Lamp, Mazda Photocell Exciter, 10 v, 7.5 amp, single contact, prefocus flanged base (for exposing).
2	Ammeter, 0–10 amp, with illumination feature, a-c Model, *744*, Weston Electrical Instrument Corporation.
3	Resistor, adjustable, 25 ohm, 25 w, Cat. No. *0365*, Ohmite Manufacturing Company.
4	Lamp, 6.2 v, miniature screw base (for ammeter scale); and Socket, Cat. No. *CH109*, Drake Manufacturing Company.
5	Switch, double-throw contacts, Cat. No. *BZRO-1*, Microswitch Corporation.
6	Transformer, filament, 110 v primary, 10 v, 8 amp secondary, Cat. No. *T-19E96*, Thordarson Electrical Manufacturing Company.
7	Rheostat, 15 ohm, 25 w, Model *H*, Cat. No. *0146*, with Cat. No. *5129* Knob, Ohmite Manufacturing Company.
8A	Rheostat, 200 ohm, 100 w, Model *K*, Cat. No. *045-2*, with Cat. No. *5129* Knob, Ohmite Manufacturing Company.
8B	Switch, toggle, single pole, single throw, 3 amp, Cat. No. *354*, Ohmite Manufacturing Company (attached to and actuated by 200-ohm rheostat).
9	Cord, Type *S*, 2-conductor, No. *16* awg.
10	Plug cap, parallel blade, 250 v, 10 amp, Cat. No. *70124*, Cutler Hammer, Inc.

TELEVISION AND THE MOTION PICTURE THEATER*

LESTER B. ISAAC**

Summary.—*The problems of television entertainment in motion picture theaters are discussed from the exhibitors' standpoint, including present equipment available, location in the theater, scheduling of programs, and the economic considerations. The author wishes to emphasize that his comments in no way reflect the opinions of Loew's Incorporated or any of its officers or executives. He offers the following paper as his personal thoughts on a widely discussed subject.*

After much talk and probably some concern on the part of motion picture exhibitors as to how television will affect their theaters, I have come to the conclusion that it is about time that something was said to alleviate their fears.

Merely as a novelty, television cannot bring patrons to the box office. It must be entertainment comparable to that to which they have been so long accustomed. For the past several years, I have made a careful investigation and study of the television situation. It is my opinion that motion pictures are here to stay, and will enjoy their universal popularity for many, many years to come. Yet there are many in the television field who will not agree with me and, to the contrary, even make claims that the new art will eventually replace the motion picture.

I think, however, it may be acknowledged that of all the claims that have been made to date regarding the practical possibility of television as a form of public entertainment, not one has developed as an accomplished fact. This would seem to indicate that, while making full allowance for the need for progress and vision, certain elements of the television field are day-dreaming and are much confused as to the future of television in the theater. The motion picture industry has had long practical experience in the entertainment field and I am sure those who have carefully studied this situation are not greatly alarmed. I do hope, however, that this discussion may offer some

* Presented, May 10, 1946, at the Technical Conference in New York.

** Director of Projection and Sound, Loew's Incorporated, New York.

mental relief to those exhibitors who at the present time have fears regarding the many complications and heavy expense which will be entailed through the installation of television in their theaters.

Theory is necessary in engineering and medicine, but the exhibitor cannot use the public as guinea pigs. When the product reaches the theater, it must have very definite box-office possibilities. On an average it must be profitable entertainment, for after all the real boss of the motion picture industry is the man, woman, or child who lays down the price of admission at the box office. Even with such a phenomenon as television, we must be farsighted and practical. In my opinion, what Barnum said about the credibility of the American public is no longer true today. The public shops for the best entertainment and for the most comfort.

First, let us assume that television projection room equipment is *now* available for theater use. How could such programs be handled in a practical manner? Particularly those on-the-spot pickups? Certainly it would not be practical or desirable to break into our regularly scheduled motion picture film programs. For example, suppose the theater screening of a main feature is scheduled for 12 noon. At 12:50 P.M. you receive a phone call that a fire or flood is taking place in one of our large cities, and this will be telecast at 12:55 P.M. Now in order to bring this television program to your audience, the feature picture must be stopped, after running for 55 min, with 35 min more for completion. Certainly no one, by any stretch of the imagination, can believe that theater patrons will cheerfully put up with any such interruption of the show.

It is no doubt true, of course, that when televison programs of national interest are prepared in advance, a schedule could be arranged to meet the requirements of such telecast. But this telecast must be arranged at a date which will allow the theaters to publicize the fact to their patrons. If, however, the telecast program is of wide national interest, why should the public go to the theater and pay admission, when such a telecast might be seen on their own home receivers? There has been wide talk about the likelihood of using television in the theaters at some comparatively immediate date. Therefore, I think we must now seriously consider the fact that at the present time, so far as I know, there is no television projector available for *practical use* in motion picture theaters.

I want to emphasize the words "practical use," as this will be discussed later in this paper. I concede that there are at least two so-

called theater television projectors—there may be more—but I have seen only two demonstrated so far. The first projector was demonstrated at the old New Yorker Theater in New York City several years ago. The second was demonstrated to me on April 5, 1946, in Schenectady. I can merely give my impression of these two demonstrations.

The demonstration at the New Yorker Theater several years ago did not impress me favorably because of poor illumination and only fair definition. The main portion of the program was a prize fight being held at Madison Square Garden. This telecast was not through the ether, but was brought to the projector by tuned telephone wire circuits, not coaxial cable. The television projector was located in the loge section of the balcony, at a distance of approximately 70 ft from the screen, and projected an image of about 15 $\times$ 20 ft. I am given to understand that this projector is limited to a projection distance of from 70 to 80 ft.

In the Fall of 1945, I had an opportunity to examine this television projector again. Although the television projector was not demonstrated at that time, it was my conclusion that no obvious improvements had been made upon it since it was demonstrated at the New Yorker Theater.

Because of the design and bulk of this projector, it could not be installed in any theater projection room, even if it were possible to project the image at greater distances than that for which this particular model was designed. This will be discussed later in the paper.

The demonstration of the second television projector was given in the very small auditorium of the Schenectady Civic Playhouse. The program consisted of motion picture film and live talent, which was picked up by the television cameras and fed by coaxial cable through a special low-power microwave frequency modulation transmitter located on a tower near the studio. The transmitter output was beamed by a directional transmitter antenna toward the theater, where it was picked up by another directional antenna. It was then energized by way of coaxial cable through a special frequency modulation picture receiver, which fed the picture to the projector. Sound was transmitted from the studio by means of radio link.

The size of the projected image was 11 $\times$ 15 ft, at a projection distance of 30 ft. The light and definition from this projector are superior to that of any others I have witnessed, although there is still room for considerable improvement before it can be used for practical,

profitable entertainment in motion picture theaters. I have been informed that 30 ft is the maximum projection distance for this projector. Projection distances in present-day theaters are from 60 to 210 ft, but no average is available.

The two television projectors as herein outlined are known as the "instantaneous system." When a program is received from its source, it is instantly projected on the screen. There is another type known as the "storage system." The storage system takes the television program from its source, either off the air or through wire, and records it upon a supersensitive 35-mm film which is processed in from 2 to 5 min, and then projected through standard 35-mm motion picture projectors. This latter system seems practical, but I do not know how it would look on the screen, as I have never had the pleasure of witnessing a demonstration. Granted, however, that it seems practical from an equipment point of view, why is it necessary, and what obvious advantage has it? It seems to me to be just another way of presenting a newsreel. We certainly could not present this system to audiences as true television, and I should like to ask what is wrong with our present-day newsreel. I think a splendid job is being done in bringing visually and orally news subjects of great current interest to the public. Certainly a bang-up job was done in World War II.

Now let us consider the practicability of the two television projectors which I have seen demonstrated. Both have very limited projection distances, and just where could they be installed in present-day theaters? Engineers and manufacturers have made many statements regarding the installation of television projectors in theaters. Therefore, I will first give the claims as made, and then give the negative side.

Claim: Because of limited projection distance, the television projector could be installed on the rear of the stage and the image projected through a translucent screen.

Negative: Most theaters throughout the United States have only sufficient room for the present horn system. If there were sufficient room back of the screen, what would happen to the motion picture screen and horn system? Most theaters are not equipped to permit flying of the screen, let alone the horns.

In those theaters which may be equipped to fly the screen and move the regular horns off stage to permit rear projection television, is there a definite idea as to the added cost of labor required? The great majority of theaters cannot stand the additional expense.

Claim: A television projector could be installed in the orchestra pit.

Negative: Most theaters do not have orchestra pits.

Claim: A television projector could be installed in the basement, just in front of present picture screen, using either a regular mirror or periscope system to project the image on the regular screen.

Negative: Most theaters do not have a basement in the screen area. Basements are usually under the lobby and rear of the auditorium for heating and ventilating units and for use of stores which may be a part of the project.

There may be other theater television projectors on paper, but whether on paper or not *if* television is to become a part of the motion picture theater, the design and manufacture of television theater projectors must meet the requirements of practical, profitable theater operation.

Theater television projectors should be designed and manufactured in such a manner that they could be installed including the receiver and all its controls, in the present theater projection room beside the motion picture projectors. The present film amplifiers and loudspeaker equipment should be utilized for the oral part of television programs.

This type of design and installation is a *must,* otherwise any attempt to install the equipment in places other than those mentioned here will cause jurisdictional labor disputes. Such disputes would put the exhibitor right in the middle and, further, make the cost of operation so great that it would be much more economical to install live stage shows.

In closing, I repeat what I said at the beginning of this paper: I fail to see the box-office value of television in conjunction with motion picture theater operation unless it may be the televising of coming feature trailers to homes. Of course, nothing is impossible; but things that are possible can often be highly impractical. The two opinions I have indicated in this paper are that *the show must go on,* and the *show must pay.* All that I have seen or heard about television for motion picture entertainment makes me believe that it is by no means ready for general use in motion picture theaters. And it is unfair to halt progress in many other directions while waiting for that extremely indefinite period when the overwhelming number, not just a few theaters, can afford to install television.

TECHNICAL PROBLEMS OF FILM PRODUCTION FOR THE NAVY'S SPECIAL TRAINING DEVICES*

H. S. MONROE**

Summary.—*The production of films for the Navy's Special Training Devices involved a large number of special problems peculiar to this work, in addition to all the usual problems of film production. These special problems were caused by the urgency of war, the conditions under which the films were used, the necessity for maximum realism, and the need to provide for assessing the student's work.*

Since many of the devices around which these problems revolve are still in process of development, this will be in no sense a description of the devices, or of the films which are used with them. I will attempt, simply, to sketch out a few of the technical motion picture problems which were encountered. Some of these were peculiar to this work and all of them were encountered in what might be called a more virulent form.

First were the problems caused directly by the fact that the devices were for war training and were developed and produced under the pressure of a war emergency. Any new device believed to have merit for training was wanted immediately. If the device required film, it was important that the film should be ready at the same time as the device. With the very special requirements often involved for the film, this meant starting production while the device was still in the blueprint or even the early drawing-board stage.

As a result, the film was always a lap or two behind the changes being made in the device, and it was frequently necessary to scrap all we had done and start over with the deadline only a few weeks away. Sometimes the film was completed only to discover, when it was tried in the prototype device, that some unforeseen condition, or unreported change, had made it entirely unsuitable. Everything, then, had to be held up while a new film was made under the greatest conceivable pressure.

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** Formerly, Atlas Educational Film Company, Oak Park, Ill.

Another result of the war urgency was that little time could be spared for experimentation to determine the best method of obtaining the desired results. It was usually necessary to proceed along a line that looked promising, without trying others that might prove equally so. If the adopted method worked out, so much time was saved that it was considered worth the risk of having to scrap all that work and start over. In some cases, as in equipment manufacture, more than one method might be tried concurrently, and the most successful be finally adopted.

Another group of problems arose from the conditions under which the devices were to be used. A device such as the Waller trainer[1] does a magnificent training job where there is sufficient space and permanence for its installation; but the devices which produced our headaches were for installation on shipboard and at advanced bases. This meant that a lot of them were needed and, where we could use standard projectors, they were 16 mm because we could get more of them in a hurry.

To get sufficient movement of the gun or turret in tracking plane images on the screen, a large screen was necessary, and the enlargement from 16-mm film was of the order of 380 diameters. Even using fine-grain release positive for prints gave a noticeable loss of sharpness when the screen was viewed from the gunner's position only ten feet away.

When a 15-mm wide angle projection lens had to be used to save space, the result left much to be desired. This gave us no leeway at all for any loss of sharpness in any of the steps through which the pictures passed during production. Also, using such a wide-angle lens for projection on a flat screen introduced a distortion. This complicated the problems of definition and of scoring, of which I shall say more later.

Devices installed on shipboard, at advanced bases, and even at some training stations within our own borders, encountered climatic conditions which certainly did not prolong print life. This problem was further complicated by the difficulty of giving projectors adequate maintenance, and by the necessity of using many inexperienced operators.

Many methods of print protection were tried, but even so, prints were often returned with the emulsion scraped completely off of large areas, and whole rows of sprocket holes pulled out. Because of problems of synchronization, to be discussed later, every effort was

made to keep them going as long as possible since such films had to be returned to the distribution center for repair. However, no film projected continuously all day long, day after day, through a gate infrequently cleaned, at high temperature and humidity, will last indefinitely.

The second major class of problems arose out of the nature of the devices themselves. One of their main purposes was to reproduce, as closely as possible, the conditions which the student would meet in actual combat, and to keep him alive to learn from his mistakes. This made important the greatest possible realism in all the films, both as to sight and to sound.

Every effort was made to give the student the impression that he was actually aboard a ship or plane. Where the conditions under which the pictures were made precluded the showing of actual parts in the foreground, these were introduced by traveling mattes. Since the films were so highly magnified in use, the mattes had to be aligned with great accuracy so as to avoid any suggestion of matte line which would give the show away.

Special atmospheric conditions which the student might encounter in the course of his duty also had to be reproduced. Often the right conditions could not be obtained at the time the pictures were made and, in at least one case, the required conditions were changed after the pictures had been taken. Since it was impossible to arrange for reshooting, it was necessary to produce the effects in the laboratory. Any effects man will recognize the difficulties of producing an authentic picture of a ship gradually appearing as you approach it through the haze, from a negative made on a clear sunny day!

Realism was further enhanced by sound tracks carrying the sounds which the student might expect to hear in actual combat. For the most efficient training, the movements of the target had to be predetermined; consequently actual battle photography could seldom be used. Whether the scenes were staged for live photography or shot from models, authentic sound could not be recorded at the same time.

The problem then, was either to cut recordings of actual battle sound to synchronize with what was shown on the screen or to produce a synthetic track which could be mixed with a general background of battle noise to make the final track. There was also the problem of reproducing the sound of gunfire at realistic volume levels with the equipment available, but in this case we just did the best we could and let it go at that.

In order to be effective, a training device must also evaluate the work of the student and inform him of his progress. This was the most serious source of problems, and the cause of those most peculiar to this special type of film. In the case of targets having rapid motion relative to the gunner, always present when aircraft are involved, the most important aspect was determining the correct point of aim. Where the film was produced by live photography, it required careful assessment to determine from it this relative movement, and ballistic calculations to compute the correct lead and range correction.

In addition to the difficulties inherent in this process, we had to face the following facts: No pilot, under actual flying conditions, can fly a theoretically perfect attack. Such an attack, however, is far better for teaching the principles of correct aim than one containing the vagaries of actual flight. Consequently we made many of the films by mechanical animation, using models.

In this method, the movement of the student's position, in either plane or ship, and of the target, are calculated and then translated into the movement of the target relative to the student's position as it will appear on the screen. At the same time, the correct point of aim for the target position of each frame is computed.

The point of aim may be indicated on another film which will be operated in synchronism with the target film, or on the target film itself. In the first case, the usual arrangement was two standard 16-mm projectors with their film propelling mechanisms geared together through a connecting shaft. The sound tracks of the two films were used simply to increase the realism of the student's situation by reproducing the sounds of the plane in which he was supposed to be flying and of his own gun when he fired it, or other sound appropriate to the particular type of trainer involved.

To make the scoring at all accurate, the images shown by the two projectors had to be aligned exactly. Not only did individual projectors vary as to their optical alignment, but it soon became apparent that it was practically impossible to make 16-mm prints in quantity which would show the center of the image at exactly the same spot. We found it necessary, therefore, to place at the beginning of each film a fairly long strip of alignment leader having a pattern by which the two images could be exactly aligned for that particular installation and that pair of films.

All steps leading up to the master negative from which the release prints were made had to be performed with the greatest precision.

We even obtained special length rolls of 16-mm stock so that the whole film, including the alignment leader, could be printed on one piece. These precautions were to ensure that alignment, once established, would be preserved throughout.

Training activities using the films were instructed to keep pairs together and, in case one film required repair, to return both to the distribution center rather than attempt to repair it in the field. The loss of a frame or two in splicing would place the remainder of the film out of synchronism, and field activities had neither the equipment nor the experience to correct this.

Problems of synchronism were avoided when the scoring control was placed on the same film as the target, but other problems were introduced. In some of the single film trainers the sound track was used as the scoring control. This might be done by having the track carry a tone whose frequency was a function of a quantity involved in the student's problem. If this track were to be made by the use of a variable frequency oscillator, the problem arose of trying to adjust the frequency with sufficient accuracy while the film was running through the recorder at 90 ft a min.

Experiments were made with a method of producing the track photographically, but that method had a lot of problems all its own, and no entirely satisfactory method of producing this type of control track had been developed up to the close of the war.

Another type was an unmodulated track having short "blips" of fixed frequency which, when amplified, would operate a scoring mechanism through a suitable relay. Because of the uniform length of the blips, and the sharp attack and cutoff required, it was found most convenient to produce such tracks photographically on a modified animation stand. The final prints in both the cases I have described were made in the usual way from separate sound and picture negatives, so the problems at that stage were simply the usual ones encountered by any laboratory.

Another type of film, however, dispensed with the sound track entirely and used the space it would ordinarily occupy on the film, together with the space between frames, for signals to indicate the correct point of aim. These had to be aligned with the picture within tolerances of two thousandths of an inch, so they had to be on the same negative.

Since the scoring mechanism employed photocells, accurate scoring required the greatest possible difference in the light hitting the cell

between the correct aim position and any other. This meant high contrast in the scoring area of the film, and was analogous to the situation in a variable-area sound track. But in that case the track is printed from a separate film, often having a different emulsion specially designed for the purpose and almost universally given different development. In these films, on the other hand, it was necessary to produce the equivalent of a variable-area track on the same film as the picture negative, without degrading contrast in the scoring signals and without producing a "soot-and-whitewash" picture.

The history of this work, throughout the war, was a seesaw of improving control at the expense of picture, then picture at the expense of control, the switch being made in each case when the neglected part began to give trouble. Some research was begun on methods using color filters to control the contrast of the two parts of the film. Means of increasing the inherent contrast of the scoring signals which were photographed were also sought, but the problem cannot be said to have been entirely solved when hostilities ceased.

Even if it had been possible to make an ideal scoring signal with a picture that still looked like something, machines would nevertheless vary as to the score they gave a student because of variation in the sensitivity of the photocell and its amplifier, in the width of the mask, in the voltage of the power supply, and in the adjustment of the trainer.

To a certain extent this was overcome by developing a leader which projected a stationary target that the rawest novice could hit. Thus eliminating the student's error, we were able to measure the variation in machines and films. The scoring signals on the film, instead of remaining stationary at the point of correct aim, moved past it at a uniform rate. The score thus obtained enabled a correction factor to be applied to the scores subsequently made on that machine, in that location, with that film, to make them comparable with scores obtained in other situations.

In addition to all these problems, which were more or less inherent in the training situation, others were introduced by the special design of certain devices. These ranged from such comparatively simple things as frames half the standard height, through extreme wide angle projection from standard film onto a hemispherical screen, to the use of polarizing emulsions to make an image, or part of one, appear to disappear at will. Throughout, there was a gradual in-

crease in the use of color, just as there has been in the entertainment and commercial fields, and that simply made the other problems the more difficult of solution.

Although I have been able only to catalog the major problems we encountered, it must be clear that the Special Devices Division's Film Section in the Navy's Office of Research and Inventions was required to be far more than a routine procurement agency.

REFERENCE

[1] WALLER, F.: "The Waller Flexible Gunnery Trainer," *J. Soc. Mot. Pict. Eng.*, **47**, 1 (July 1946), p. 73.

AN IMPROVED 200-MIL PUSH-PULL DENSITY MODULATOR*

J. G. FRAYNE,** T. B. CUNNINGHAM,** AND V. PAGLIARULO**

Summary.—*A completely new variable-density modulator utilizing a three ribbon push-pull valve is described. The entire valve is sealed by the force of the Alnico V permanent magnet on the Permendur pole pieces. Signal is applied to the center ribbon and noise-reduction currents are applied to the outer ribbons. True class A push-pull operation is obtained from the two component single ribbon valves by the use of an inverter prism which aligns the modulating and noise-reduction edges of each aperture.*

An anamorphote condenser lens is used to eliminate lamp filament striations at the valve ribbon plane. An anamorphote objective lens gives a 4:1 reduction of the valve aperture in the vertical plane at the film and a 2:1 reduction along the length of the sound track. A meter is supplied to measure exposure as well as setting up "bias." A photocell monitor is supplied and a "blooping" light for indicating synchronous start marks.

Mathematical analysis of the exposure produced by the modulating ribbon is appended as well as a similar analysis of the four ribbon push-pull valve which the new valve supersedes.

Introduction.—The Western Electric push-pull variable-density system utilizing the *RA-1061* type light valve has been in wide use in sound picture recording for a number of years. The methods currently employed are essentially those described by Frayne and Silent.[1] The original push-pull density modulator was built around the *RA-1061* light valve, which is a four ribbon structure, each pair of ribbons defining a variable slit which is focused on the sound negative. The sound currents actuate the ribbon pairs in opposite phase, one pair closing while the other is opened. At the same time, superimposed noise reduction currents are applied in phase to each pair of ribbons. The cancellation in reproduction of the in-phase noise reduction frequencies has been one of the principal advantages of the push-pull system.

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** Electrical Research Products Division, Western Electric Company, Hollywood.

The original push-pull valve was superimposed on a modulator previously designed for recording a standard 100-mil density track. Some improvements, however, were introduced in the optical system in order to reduce the distortion attributed to the so-called "ribbon velocity" effect.[2] For example, a 4:1 optical reduction of the one-mil valve ribbon slit was attained by the use of a special 4:1 objective lens which replaced the *KS-7325* 2:1 objective lens previously employed. With this objective, a 100-mil push-pull density track was obtained. Later, the demand grew for a high-quality 200-mil push-pull density track, and this was obtained by mounting a small cylinder lens adjacent to the film working in conjunction with the standard 2:1 objective lens. With either arrangement, the width of the image was effectively 0.25 mil.

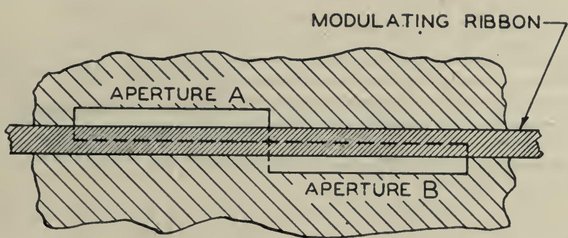

FIG. 1. Illustrating push-pull modulation by single ribbon.

The modulator described in this paper represents a completely integrated design retaining the well-proved principles of the light valve and incorporating new and improved designs in every important component of the complete modulator. Before finally deciding on retaining the light valve as the basic light modulating device, much time and effort were spent in searching for other devices and methods which would give the same excellence of performance as had been attained under operating conditions with the light valve. Since none of the devices or methods studied gave comparable performance when viewed from every possible standpoint, it was decided to retain the light valve as the basic modulating device in the new modulator.

Design Principles of Three Ribbon Valve.—Since the light valve is the most vital component in the modulator, the principles underlying the performance of the new valve will first be described. The guiding principles behind the design were simplification of manufacture, ease of adjustment, stability of operation, and fidelity of re-

sponse. In line with simplification, a very thorough study was made of the number of ribbons required to lay down a push-pull density track. It will be recalled that the *RA-1061* valve required the accurate alignment and almost identical tuning of four separate ribbons. A simple study showed that two push-pull tracks could be made with a single ribbon, as shown in Fig. 1, the apertures *A* and *B* being modulated in a push-pull manner by the movement of the ribbon. In order to obtain noise reduction with a single modulating ribbon, ribbons *1* and *3* of Fig. 2, which serve to define the fixed edges of the apertures, may be made to move in accordance with the impressed noise reduction currents. Thus, a total of three ribbons, one for signal and two for noise reduction, is all that is necessary for push-pull modulation of the light transmitted by the two apertures.

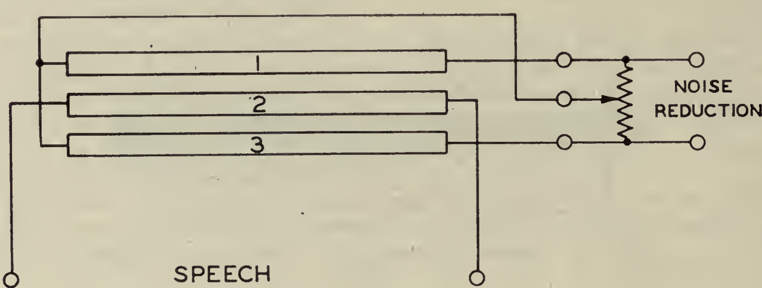

FIG. 2. Speech and noise-reduction connections for a three ribbon push-pull valve.

The electrical connections for speech and noise reduction are shown in Fig. 2. Ribbons *2* and *3* are effectively shunted by the 2-ohm potentiometer which is used to correct for any variation in sensitivity of either noise reduction ribbon, the bias currents in each ribbon being adjusted in order to obtain equal biased spacing for each aperture. It will be noted that the noise reduction and speech currents are isolated electrically. This has several practical advantages. First, it eliminates the heating effect which would otherwise be introduced in the speech ribbon by the bias currents, thereby stabilizing its tuning frequency. It permits the direct connection of the speech ribbon to the secondary of the light valve transformer, instead of working through a simplex circuit, as has been customary. This permits a lower impedance light valve circuit, which is very effective in reducing the height of the resonance peak. While the central ribbon is tuned

to a suitable high frequency the separate noise reduction ribbons may be tuned considerably lower, thus reducing the amount of bias current required and at the same time reducing the heating effect, with consequent improved stabilization of their tuning and positioning.

It is obvious from Fig. 1 that the two apertures of the push-pull valve are offset physically and that some means must be provided to make their images collinear at the film plane. The offset apertures in the *RA-1061* valve are brought into line by means of refractor plates, commonly known as "sawbucks." In the latter valve, the alignment presents no great problem since the center line of the images remains aligned irrespective of the amount of bias applied to the ribbons. In the three ribbon valve, however, the problem is more difficult in view of the fact that the bias is applied to an opposite edge of each aperture. Thus, if the apertures are aligned for the unmodulated unbiased condition, they will not be aligned when any bias current is applied to the noise reduction ribbons. There are three possible alignments which will be referred to as Cases 1, 2, and 3.

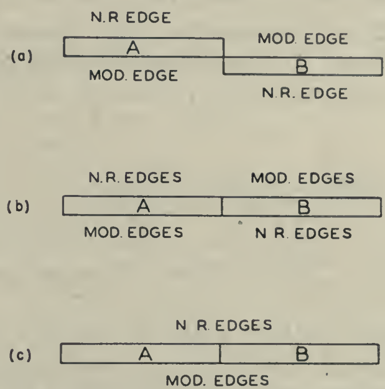

FIG. 3. Illustrating different alignments of apertures in three ribbon valve.

Case 1 is shown in Fig. 3a. It will be observed that the modulated edges are in alignment for the unmodulated, unbiased condition. The noise-reduction edges are not aligned for any condition except that of 100 per cent closure.

Case 2 is shown in Fig. 3b, in which the noise reduction edge of one aperture is aligned with the modulating edge of the second aperture. The apertures will remain aligned only for the unbiased condition, becoming more and more out of alignment as the bias current is increased.

Case 3 is shown in Fig. 3c and is obtained from Fig. 3b by the optical inversion of Image *B*. This brings the noise reduction and modulating edges, respectively, in line and the images of the apertures will stay in alignment at the film plane irrespective of the amount of bias applied to the ribbons.

The inversion of Image *B* is obtained by passing the light from the

corresponding aperture through an inverting prism of the type shown in Fig. 4. The passage of the light from aperture B through the glass prism is compensated by the addition of a rectangular prism, generally known as the compensator, in the beam from aperture A. The images of the two apertures are brought together at the film plane simply by tilting the compensator. The method of mounting and adjusting the prisms is discussed in detail later in the paper.

Distortion in Three Ribbon Valve.—The three ribbon push-pull valve consists essentially of two single ribbon valves with noise reduction applied in each case to the outer ribbon defining the aperture. The recording exposure characteristics of single and double ribbon valves have previously been described.[3] As a result, it is well known that the distortion produced by the so-called ribbon velocity effect is more pronounced in single than in double ribbon valves. For this reason, the two ribbon valve has been generally favored in light valve sound recording systems and the *RA-1061* push-pull valve referred to

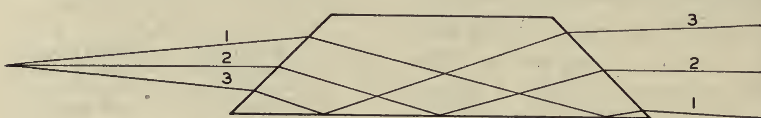

FIG. 4. Action of inverting prism on beam from one aperture.

above utilized a pair of such light valves to obtain a push-pull sound track. The question arises, therefore, as to what distortion may be introduced by using two single ribbon component valves in recording a push-pull sound track. The three methods of aligning the apertures shown in Fig. 3 have been analyzed mathematically. Only the conclusions will be referred to here, since the complete analysis appears in the Appendix. Thus, for Fig. 3a the characteristic obtained from ideal push-pull reproduction of the film recorded in this manner is as follows:

$$\text{Output} = \frac{4}{\omega}\left[J_1 \frac{(\omega b)}{v} \sin \omega \left(t_0 + \frac{a}{v}\right) - \frac{1}{2} J_2 \frac{(2\omega b)}{v} \sin 2\omega \left(t_0 + \frac{a}{v}\right) + \frac{1}{3} J_3 \left(\frac{3\omega b}{v}\right) \sin 3\omega \left(t_0 + \frac{a}{v}\right) + \ldots\ldots\right].$$

It will be noted that, in addition to the fundamental, both odd and even harmonics are present. The presence of the even harmonics indicates that the alignment of Fig. 3a does not permit true push-pull reproduction from the track recorded in this manner.

The characteristic resulting from Fig. 3b is given by

$$\text{Output} = \frac{4}{\omega}\Bigg[J_1 \frac{(\omega b)}{v} \cos \frac{\omega a}{2v} \sin \omega \left(t_0 + \frac{a}{2v}\right) - \frac{1}{2} J_2 \left(\frac{(2\omega b)}{v}\right) \cos \frac{2\omega b}{2v} \sin 2\omega \left(t_0 + \frac{a}{2v}\right) + \frac{1}{3} J_3 \frac{(3\omega b)}{v} \cos \frac{3\omega a}{2v} \sin 3\omega \left(t_0 + \frac{a}{2v}\right) - \ldots\ldots + \ldots\ldots\ldots\Bigg].$$

Here again it will be observed that there is no cancellation of the even harmonic components introduced by the ribbon velocity effect. This condition results in both cases from the fact that the even harmonics are recorded in the same phase as the fundamental, as will be noted in the Appendix from Eqs (*5*) and (*10*) in Case 1 and Eq (*14*) in Case 2.

In the alignment of Fig. 3c, where the image of aperture B is inverted, the resulting push-pull characteristics is given by

$$\text{Output} = \frac{4}{\omega}\left[J_1 \frac{(\omega b)}{v} \sin \omega \left(t_0 + \frac{a}{v}\right) + \frac{1}{3} J_3 \frac{(3\omega b)}{v} \sin 3\omega \left(t_0 + \frac{a}{v}\right) + \ldots\right].$$

The inversion of the image of aperture B results in complete cancellation of the even harmonics since in this case these components from the two valve apertures are recorded in opposite phase relative to their respective fundamentals, as indicated in Eqs (*5*) and (*19*). For this reason, the alignment of Fig. 3c has been adopted in the present three ribbon valve.

As a comparison with the performance of this valve, it is of interest to note the characteristic of the present standard *RA-1061* four ribbon structure. It is given by the following equation:

$$\text{Output} = E_2 - E_1 = \frac{8}{\omega}\Bigg[J_1 \frac{(\omega b)}{2v} \cos \frac{\omega a}{2v} \sin \omega t_0 + \frac{1}{3} J_3 \frac{(3\omega b)}{2v} \cos \frac{3\omega a}{2v} \sin 3\omega t_0 + \ldots\Bigg].$$

It will be noted that even harmonics are absent in the track recorded with this valve, but that the odd harmonics are present.

The theoretical exposure frequency characteristics obtained from the mathematical expressions for Cases 3 and 4 are shown graphically in Fig. 5. Because of the high second harmonic content of Cases 1 and 2, these valves have not been considered since a valve with such a degree of second harmonic distortion would not be acceptable in modern sound recording channels. The curves of Fig. 5 are calculated for an effective image width of 0.15 mil, which was determined

from 60- to 7000-cycle intermodulation measurements.[3] Although the geometric width of the image is approximately 0.2 mil, the effective width is considerably less, apparently because of uneven illumination of the slit. Also, the theoretical harmonic content calculated from Eq (*23*) of the Appendix on the basis of this image width agrees very closely with the experimental values determined from actual recordings. It should be pointed out that the harmonic values shown in Fig. 4 are based on 100 per cent modulation of the aperture. Since the light valve spacing only attains its nominal value for the 100 per cent modulation condition, actual harmonic content in a typical recording is considerably less since the action of the bias

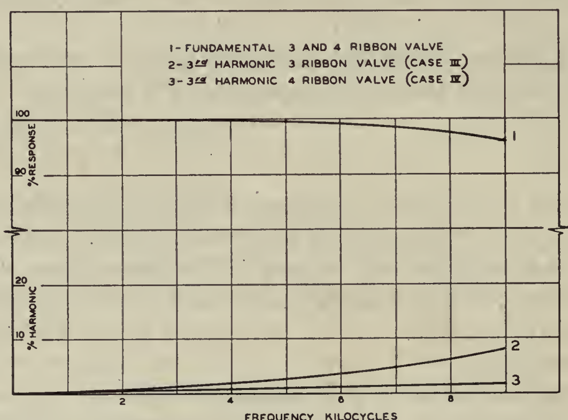

FIG. 5. Frequency response and harmonic distortion of three and four ribbon valve.

results in a smaller image width. The comparison of Cases 3 and 4 shows that the fundamental frequency response is the same for the three and four ribbon valves, each being spaced to a nominal value of one mil. The amplitude of the third harmonic is slightly greater for the former. However, if we consider 9000 cycles as the upper limit of reproduction, we are interested only in the third harmonics of fundamental frequencies lying below 3000 cycles. At these fundamental frequencies, the curves of Fig. 4 show that the third harmonic in the three ribbon valve is only one per cent of the value of the fundamental. With the second harmonic completely cancelled out, the question of harmonic distortion in the exposure characteristic of this light valve is academic. This is substantiated by experimental re-

cordings which agree very closely with the above theoretical data. It should be pointed out, however, that either single component of the push-pull track will show an appreciable second harmonic, since the elimination of this harmonic is only attained in push-pull reproduction. The use of a single track in this modulator is, therefore, not recommended for high-quality single track reproduction, but is a perfectly satisfactory medium for editing and other studio purposes. Also, the current practice of using reverse bias on the ribbons is not recommended with this valve, as any spacing wider than one mil leads to increased distortion.

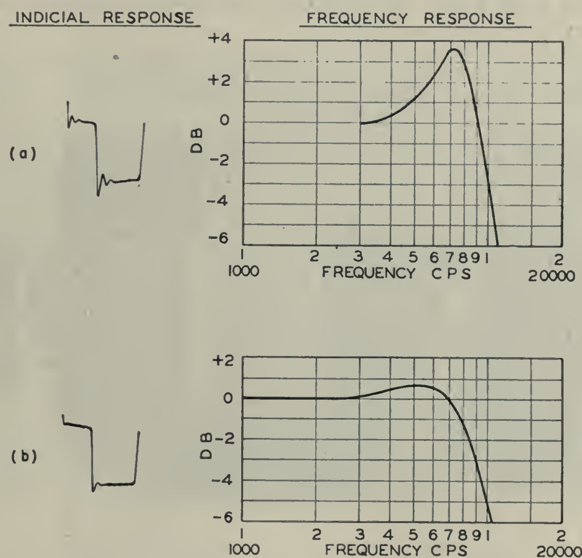

FIG. 6.

Dynamic Characteristics of the Valve.—In the design of the *RA-1238* valve, a marked reduction in the peak response as compared to that of older type valves was considered imperative. It has been well established that a source of some instability in existing light valves is the relatively high amplitude oscillations induced at the resonant frequency of the ribbons by the impact of sharp wave front sounds. After careful consideration, the magnetic circuit discussed elsewhere in the paper was selected. It was found that this design resulted in a flux density in the air gap of around 32,000 gauss, and this in turn produced a marked lowering of the resonance peak. The

use of a single ribbon of approximately 0.5-ohm resistance, instead of the four ribbons of the *RA-1061* valve, when associated with a correspondingly low transformer secondary impedance, also was a contributing factor to lowering the height of the resonance peak. Further damping was obtained by the use of an 0.5-ohm shunt directly across the signal ribbon, the 3-db loss in power being more than compensated for by increased efficiency of the valve.

The frequency response and the indicial or square wave response for various conditions are shown in Fig. 6. Fig. 6a shows the valve response with a 0.5-ohm shunt. An effective peak of about +3.5 db is obtained while about two damped resonance oscillations result from

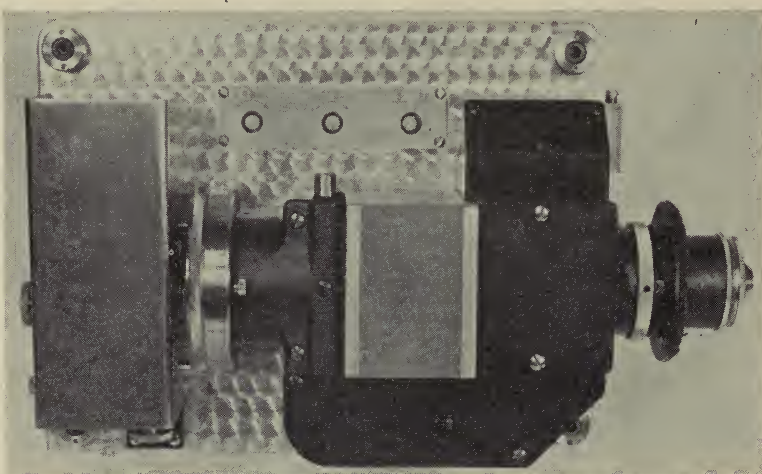

FIG. 7. Completely assembled three ribbon light valve modulator.

the application of a square wave to the light valve transformer. When a constant impedance equalizer with an attenuation characteristic conjugated to the resonance curve was inserted in the 600-ohm side of the light valve transformer, the response shown in Fig. 6b was obtained. A net rise of about 0.7 db was obtained under this condition and the oscillation under the impact of the square wave is reduced to about one cycle. The use of this constant impedance equalizer has therefore been standardized for use with the *RA-1238* light valve.

An interesting feature of this valve which is not noticeable in older designs is a pronounced shift of the resonance frequency by the high damping. The valve used in making curves of Fig. 5 was tuned to

about 8300 cps in a weak magnetic field. When completely magnetized, the peak response shifts from this value to about 7400 cycles, or a shift of about 900 cycles. The true resonance point remains at about 8500, and the valve will tend to oscillate weakly at this frequency under a sharp impact. In order not to confuse the technician tuning the valve, the undamped peak frequency is referred to as the tuning point rather than the frequency of maximum response of the magnetized light valve

General Design of Modulator.—Fig. 7 is a photograph of the completely assembled modulator. The lens assemblies, light valve, lamp bracket, shutter, deflector, exposure meter, and photocell optics, all are solidly mounted on a vertically positioned base plate in the modulator housing at right angles to the film plane. Each component part is independently adjusted during manufacture and permanently secured to the base plate. The entire optical assembly and valve can be adjusted as a unit for final focus by sliding the base plate on engaging studs located in the modulator housing. Provision is also made to shift the plate parallel to the axis of the recording drum to locate the sound track properly on the film.

The shutter operating solenoid, photocell monitor coupling unit, and exposure meter photocell mesh are installed on the back of the base plate, assuring positive alignment of all associated assemblies. Connections are made to a remote photocell amplifier through a coaxial cable. The electrical and mechanical lineup controls consisting of lamp adjustments, variable lens stop, noise reduction balance potentiometer, photocell balance potentiometer, and photocell amplifier push-pull-standard switch, are conveniently located in the modulator.

Optical System.—As indicated above in this paper, improvements in the older 200-mil objective optical system had been obtained by use of a small cylindrical lens mounted adjacent to the film and used in conjunction with the 2:1 spherical objective lens, the combination producing an effective image width of approximately 0.25 mil. This system required the use of a weak positive cylindrical lens in conjunction with the spherical objective lens and oriented so that its axis is "crossed" with the axis of the small cylindrical lens adjacent to the film in order to bring the vertical septum and end masks of the light valve into focus at the same plane as the ribbon image.

The new optical system schematic is shown in Fig. 8. The working distance from lamp to film plane has been reduced from approximately

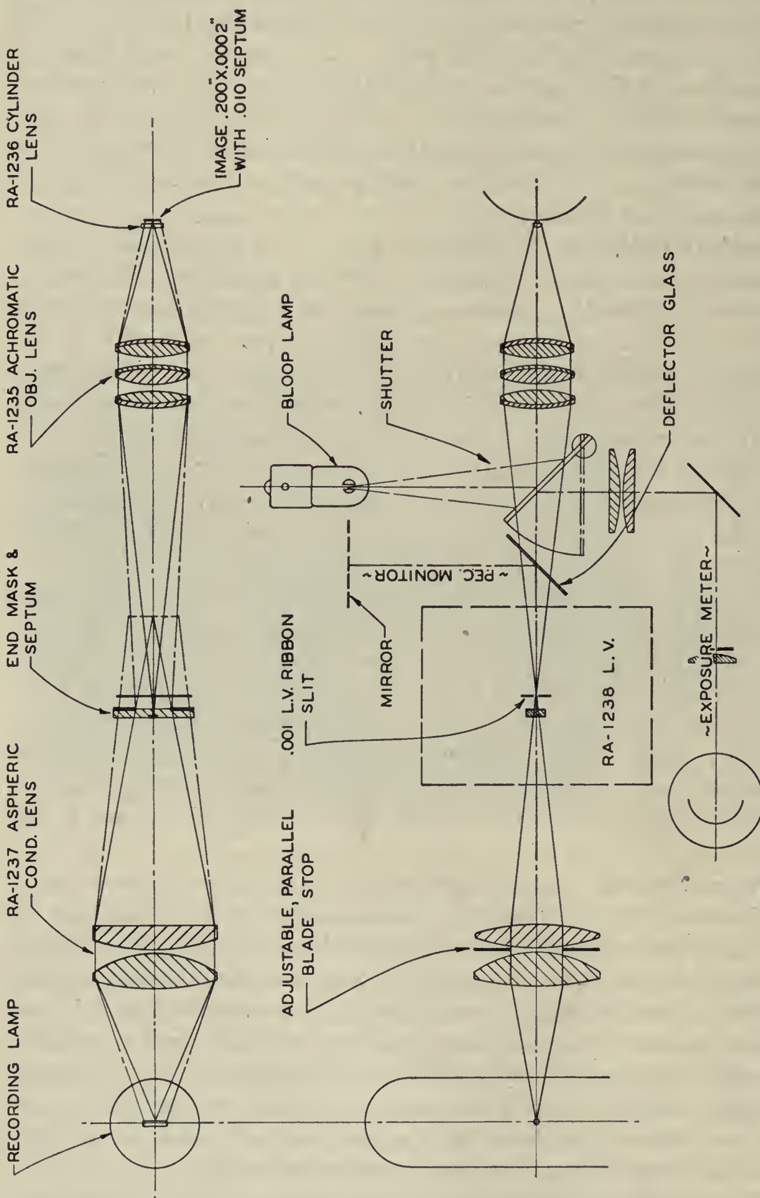

FIG. 8. Optical schematic of three ribbon light valve modulator.

13 in. in the old system to less than 11 in. in the new. This allows for more compact and rigid design. Reading from right to left are shown the *RA-1236* cylinder lens and the new shorter focal length *RA-1235* spherical objective lens which is achromatized over the spectral region to which the sound recording emulsion is most sensitive. The two elements are combined in a single mount to form an anamorphotic objective system. The septum and end masks are located behind the ribbons and are focused in the same plane as the light valve ribbon images. The inverting and compensating prisms are mounted in the light valve in front of the ribbons. The next element appearing in the system is the new *RA-1237* aspheric cylindrical condenser lens combination. This lens is designed to fill completely the objective lens system and produce an image free of lamp coil striations at the ribbon plane. This is accomplished by imaging the length of the filament at the ribbon plane and imaging the vertical coil component beyond the ribbons. An adjustable stop with a pair of blades parallel to the ribbons is included in the condenser in order to provide exposure control required by films of different speed and processing variations. The last item in the system is the new recording lamp, which is provided with a prefocused base. It is furnished in a smaller envelope than previous lamps, and operates at a color temperature of 3150 K at a current of 7.5 amp.

The photocell monitoring deflector plate is placed between the light valve and the objective lens. This deflector transmits approximately 90 per cent of the total light to the objective system, the remainder being directed to the monitor photocell. The optical system of the photocell monitor follows previous practice in that the image of the valve is focused at two separator lenses which divert each half of the push-pull image to the appropriate photocell in the monitor amplifier. A double reflecting shutter is also located in this portion of the objective path. In the closed position it blocks all light from the light valve to the film but directs the image of a bloop lamp to the film for the purpose of producing a synchronizing mark at the start of a recording "take." The other side of the shutter in the closed position deflects all of the light from the light valve into the exposure meter photocell. The optical system produces an image of the light valve at a collective lens which in turn transmits the light to the photocell. An adjustable mask located at this image point provides means for measuring the total light or each half of the image independently.

When the shutter is open for recording, neither the bloop lamp nor the exposure meter is operative.

Light Valve.—The assembled light valve coded *RA-1238* is shown in Fig. 9. A disassembled view is shown in Fig. 10. The design follows the basic principles established by Wente[4] and used in the stereophonic recording system. Referring to Fig. 10, it will be seen that the entire valve consists of three major parts: the permanent magnet, the top pole piece, and the base pole piece assemblies. These assemblies are located in opposite ends of the magnet by means of concentric shoulders which fit into concentric recesses ground into the ends of the magnet. Dowel pins in the end plates engage the magnet and ensure proper orientation of the two pole pieces.

FIG. 9. Assembled light valve.

Fig. 11 shows a cross-sectional view through the magnet and pole pieces. A careful selection of magnetic path, pole piece shape, and materials was made in order to ensure maximum flux density in the air gap. Pole pieces were designed to minimize leakage and to conserve space without sacrificing this requirement. These pole pieces and end plates are constructed of Permendur, selected largely because of its high flux saturation. Alnico *5* was selected for the magnet because of the high magneto-motive force which can be generated and retained in this type of material when used in a permanently closed magnetic circuit. The valve is designed on the basis of these factors and must be demagnetized and remagnetized each time it is assembled, in order to retain maximum efficiency and sensitivity. The design is such that in the assembled valve the pole pieces are saturated well below the current used in the charging coil during the magnetizing cycle. This results in an available magnetomotive force considerably in excess of that required, which ensures uniform sensitivity in a large number of valves, assuming that all other factors are held constant. The most important of these factors is the air gap adjustment and this is held to a close tolerance during manufacture and assembly. Magnetic field strength tests reveal that the

flux density realized in the air gap averages about 32,000 gauss. This is in marked contrast to the force of 16,000 to 18,000 gauss obtained in the *RA-1061* valve. The benefits realized from these improvements in design are shown in Figs. 6a and 6b and were discussed earlier in this paper.

Fig. 12 is a plan view of the light valve showing the arrangement of the clamp carriages and ribbons. Each of the two groups of clamp carriages is fastened solidly to the ends of the pole piece by means of two relatively large insulated screws. Since the center of the vibrating span coincides very closely with those of the apertures, the catenary effect or "bowing" of the ribbons is minimized. This, in turn, results in a more uniform track density for the biased condition and

FIG. 10. Sections of disassembled light valve.

more uniform modulation across the track. The net result is a more effective signal-to-noise ratio from a track recorded with this type of valve.

Although the ribbon and pole pieces are constructed of different materials, their temperature coefficients fall fairly close together and the effects of temperature variations have been reduced to a very small value. Variation in ribbon tuning is the most critical factor affected by temperature changes in the light valve and it may be used as a measure of the effect. Carefully controlled tests made over a range of −40 to +150 F produced a change of only 50 cycles in a tuning frequency of 8500 cycles. The spacing and positioning of the ribbons showed no measurable change over this range of temperature.

Benefits from the use of beryllium copper have been realized in the

new clamp carriages shown in Fig. 13. The well-known physical characteristics of this alloy[5] have permitted the design of smaller and lighter clamp carriages without any sacrifice of strength. This material has additional advantages in this particular application because it is nonmagnetic, is highly resistant to corrosion, and provides a

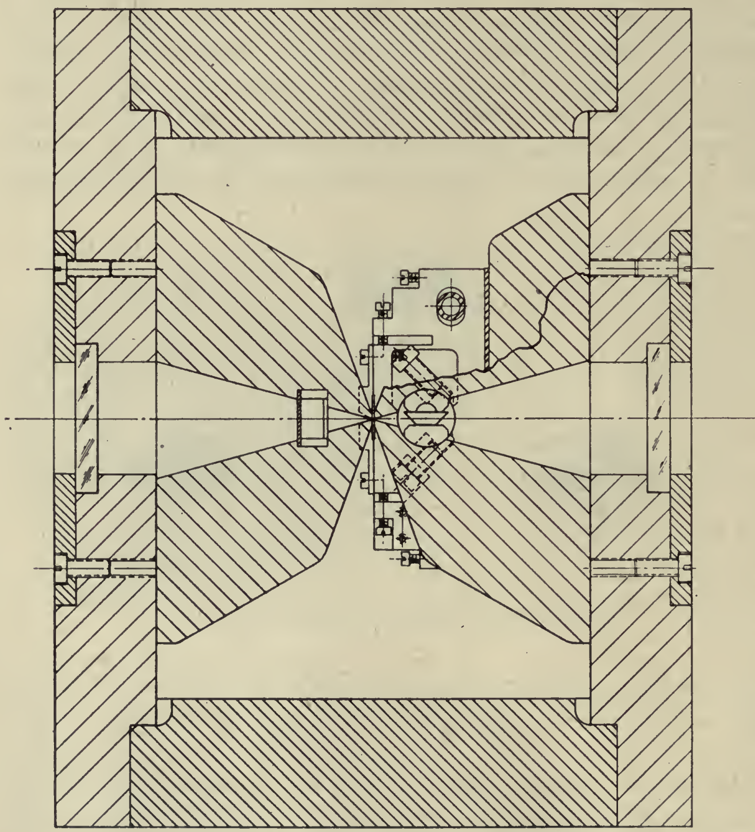

FIG. 11. Cross-sectional view of valve.

relatively hard surface at the ribbon clamp. It is an excellent electrical conductor, particularly after heat treatment. The mechanical design of the carriage has been simplified over older designs to facilitate manufacturing and assembly without loss in stability. The slot and self-locked screw arrangement shown provides easy and accurate ribbon height adjustment at assembly.

Silver contacts pressed into insulating bushings in the end plate and connected to the carriages provide electrical connections to the external circuits. A $^1/_2$-ohm shunt is permanently connected across the speech ribbon to ensure maximum damping.

As shown in Fig. 11, the inverting and compensating prisms are installed in two small metal cylinders which are located immediately

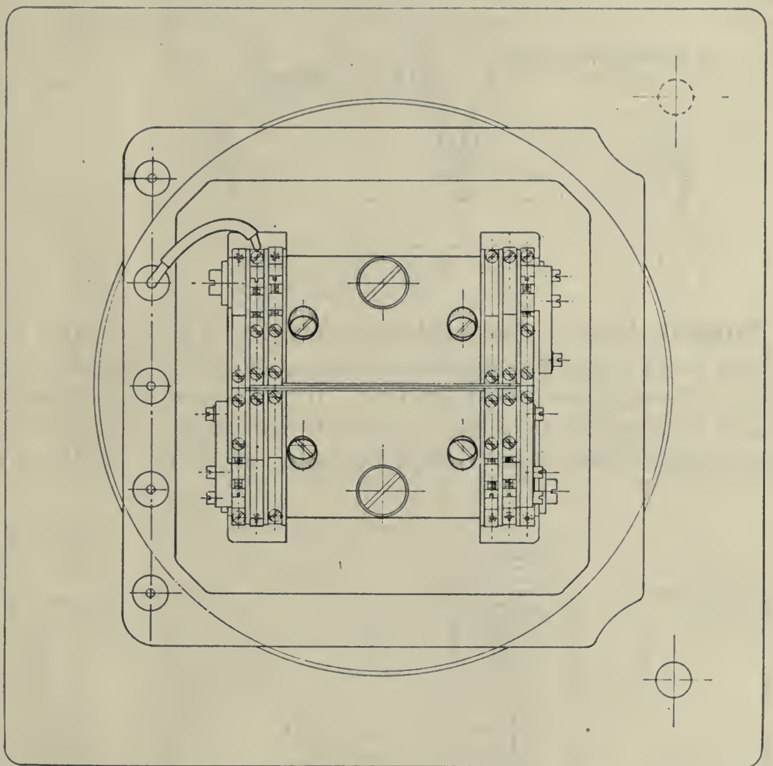

FIG. 12. Illustrating clamp carriage and ribbon arrangement.

below the ribbon apertures. These cylinders are fitted into a hole bored transversely through the pole piece so that the prism-supporting cylinders lie parallel to the ribbons. Alignment of the prisms is provided by the two opposing screws engaging the cylinders, causing them to rotate and slightly tip the prisms. When adjustment is completed, the screws are tightened to lock the cylinders in position.

Standard Valve.—For single track recording a new two ribbon

valve coded *RA-270* will be available. It will mount in the modulator in identically the same manner as the *RA-1238*, the correct track position being obtained by moving the modulator in the manner described above. All the mechanical advantages of the *RA-1238* are retained in this valve. The construction is, of course, simplified by virtue of use of one recording aperture.

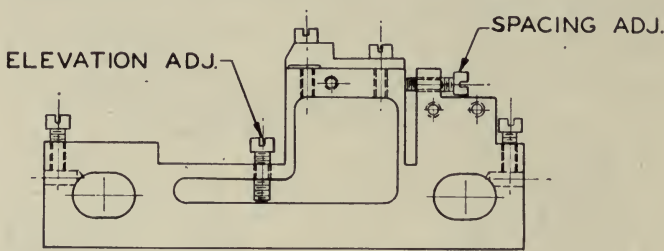

FIG. 13. Ribbon clamp carriage.

Exposure Meter.—The modulator includes a photoelectric exposure meter which measures the total amount of light passed by the valve, or by each component aperture. It thus provides a convenient means of adjusting the light intensity to the proper value for the particular film being used, and of balancing the light flux through each

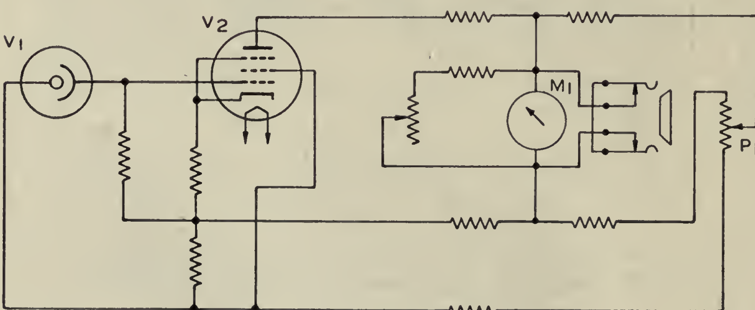

FIG. 14. Exposure meter schematic.

aperture. It may also be used for setting up noise reduction. The essential parts of this device are a blue optical filter, a *929*-type photocell, direct-current amplifier, and current meter. The reflecting surface of the shutter referred to above, when in the closed position, diverts into the photocell all of the light which would normally fall on

the objective lens. The blue filter is interposed in the light beam directly in front of the photocell. The photocell provides the input voltage to a *6SJ7* pentode, which acts as a single stage direct-current amplifier having considerable inverse feedback. The electrical schematic is shown in Fig. 14. A microammeter connected in the plate circuit of the pentode *V2* indicates the change in plate current, which is a measure of the quantity of light entering the photocell. A balancing circuit cancels the zero signal plate current so that with no light into the photocell the meter will read zero. A potentiometer permits adjustment of this balancing current in order to compensate

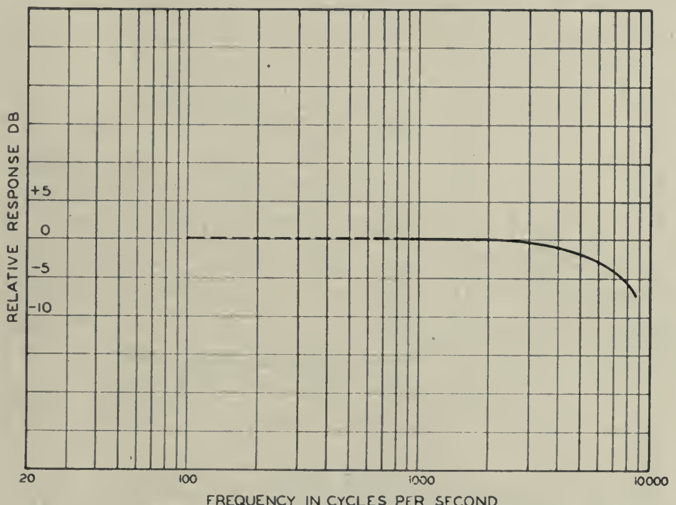

FIG. 15. Experimental film frequency characteristic of push-pull modulator.

for slight drifts in plate current. A variable resistor shunting the meter permits adjustment of sensitivity; however, the operator can always return to a permanent calibration by throwing a switch which disconnects this variable resistor and connects a calibrated shunt across the meter. The meter has two scales, one a straight linear scale, the other a decibel scale which is used primarily for setting noise reduction. On this latter scale, full-scale reading of the meter is indicated as zero db, half-scale as 6 db, quarter-scale as 12 db, *etc.*

The spectral sensitivity of the photocell in combination with the blue filter results in an over-all spectral response of the exposure

meter which is very close to that of the film. This is indicated experimentally by the fact that wide fluctuations in color temperature of the recording lamp result in identical exposure of the film providing the exposure meter reading is kept constant. There is sufficient inverse feedback that wide variations in supply voltage produce negligible changes in sensitivity.

Operating Characteristics.—The film frequency characteristics of the modulator are shown in Fig. 15. These characteristics are obtained on a print from a negative made with constant input modulation of the single speech ribbon. The sensitivity of the speech ribbon in the *RA-1238* light valve for 100 per cent modulation at 1000

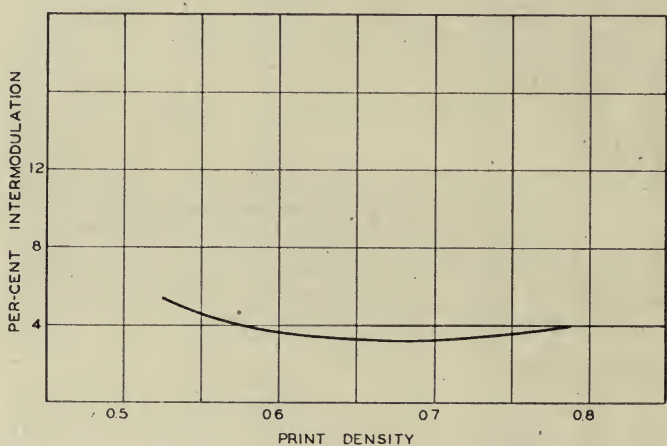

Fig. 16. Push-pull intermodulation print density characteristic of modulator.

cps requires a level of +4.5 db per 0.001 w including the power dissipated in the built-in $^1/_2$-ohm shunt.

The noise reduction ribbons which are tuned to approximately 5000 cycles require 0.080 amp for 0.001-in. excursion. Part of this current is dissipated in the 2-ohm noise reduction balancing potentiometer.

Fig. 16 shows the intermodulation distortion in a print made from a negative recorded by the *RA-1238* light valve modulator. The intermodulation test procedure follows that originally proposed by Frayne and Scoville,[3] namely, the superposition of 1000 cycles on a 60-cycle tone, the level of the 1000 cycles being 12 db below that of the lower frequency. The combined wave forms were recorded at 80 per cent

peak modulation of the ribbon. The low value of 3 per cent indicates that the modulator itself is essentially free of distortion, and the broad curve indicates a wide choice of print density for this type of push-pull recording.

The original model of the modulator and light valve were put in production test at Sound Service Studios over a period from January 18, 1946 to March 25, 1946. An entire production was recorded on the system during this period. No serious operating difficulties were encountered during this time. A single valve was used and during the entire period only one spacing adjustment was necessary. No other variations were observed, although a daily check was made of spacing and tuning. These checks were more of a precautionary measure than a necessity, since only one valve was available for this production test. The speech and music recordings made with this modulator leave little to be desired in the way of quality.

Conclusion.—The 200-mil push-pull modulator described in this paper is a completely integrated design, involving new or improved design of all the component mechanical and optical elements. It has proved to be very stable under operating conditions and at the same time gives a very high fidelity of response. The simplified structure of the three ribbon valve makes the tuning and spacing operation more simple, and the high damping results in greater stability under operating conditions. Its performance appears to be superior in every way to the earlier *RA-1061* valve that it supersedes.

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Mathematical Appendix

The following symbols are used throughout the analysis:

v = speed of film in recorder = 18,000 mils per sec

a = width of unmodulated image

b = amplitude of displacement of signal ribbon image under the influence of signal subject to limiting value $a = b$
f = signal frequency
ω = $2\pi f$ = circular frequency
t = time
y = $\pm b \sin \omega t$ = motion of the signal ribbon as a function of time
$Jn(n\omega b/v)$ = Bessel function of the first kind of order (n) and argument $n\omega b/v$
$Jn(-n\omega b/v) = (-1)^n Jn(n\omega b/v)$ Theorem in Bessel functions
S_1 = Instantaneous width of image in sound track No. 1
S_2 = Instantaneous width of image in sound track No. 2
c_1 = Exposure received by a point on the film in crossing S_1
c_2 = Exposure received by a point on the film in crossing S_2
Σ = symbol indicating summation of a number of terms in a series

CASE 1

Modulating edges of image are aligned as in Fig. 3a.

$$^*c_1 = t_1 - t_0 = S_1/v = a/v - b/v \sin \omega t_1 \tag{1}$$

$$t_1 = t_0 + a/v - b/v \sin \omega t_1 \tag{2}$$

$$\omega t_1 = \omega(t_0 + a/v) - \omega b/v \sin \omega t_1 \tag{3}$$

$$= \omega(t_0 + a/v) + 2\sum_1^\infty 1/n Jn(-n\omega b/v) \sin n\omega(t_0 + a/v) \tag{4}$$

$$c_1 = t_1 - t_0 = \frac{a}{v} + \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{v}\right) \sin n\omega \left(t_0 + \frac{a}{v}\right) \tag{5}$$

$$c_2 = t_2 - t_1 = \frac{S_2}{v} = \frac{a}{v} + \frac{b}{v} \sin \omega t_1 \tag{6}$$

By similar development as above

$$c_2 = t_2 - t_1 = \frac{a}{v} - \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{v}\right) \sin n\omega \left(t_2 - \frac{a}{v}\right) \tag{7}$$

$$t_2 - t_0 = 2a/v \tag{8}$$

$$t_2 = t_0 + 2a/v \tag{9}$$

$$c_2 = t_2 - t_1 = \frac{a}{v} - \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{v}\right) \sin n\omega \left(t_0 + \frac{a}{v}\right). \tag{10}$$

In push-pull reproduction the total output is Eq (*10*) minus Eq (*5*).

$$\text{Output} = c_2 - c_1 = -\frac{4}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{v}\right) \sin n\omega \left(t_0 + \frac{a}{v}\right) \tag{11}$$

$$= \frac{4}{\omega}\left[J_1\left(\frac{\omega b}{v}\right) \sin \omega \left(t_0 + \frac{a}{v}\right) - \frac{1}{2} J_2\left(\frac{2\omega b}{v}\right) \sin 2\omega \left(t_0 + \frac{a}{v}\right) + \frac{1}{3} J_3\left(\frac{3\omega b}{v}\right) \sin 3\omega \left(t_0 + \frac{a}{v}\right) + \ldots \right]. \quad (12)$$

CASE 2

Modulating edges of image are aligned as in Fig. 3b.

The theoretical development for the exposures in this case is identical to that of Case 1, Eqs (*5*) and (*10*), except that for this case Eq (*8*) becomes

$$*t_2 - t_0 = a/v \quad (13)$$

and Eq (*10*) becomes

$$c_2 = t_2 - t_1 = \frac{a}{v} - \frac{2}{\omega} \sum_1^\infty \frac{1}{n}\left(\frac{-n\omega b}{v}\right) \sin n\omega t_0. \quad (14)$$

Push-pull output from the film is Eq (*14*) minus Eq (*5*).

$$\text{Output} = c_2 - c_1 = -\frac{2}{\omega} \sum_1^\infty \frac{1}{n}\left[Jn\left(\frac{-n\omega b}{v}\right)\right] \left[\sin n\omega t_0 + \sin n\omega\left(t_0 + \frac{a}{v}\right)\right] \quad (15)$$

$$= -\frac{4}{\omega} \sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{v}\right) \cos \frac{n\omega a}{2v} \sin n\omega\left(t_0 + \frac{a}{2v}\right). \quad (16)$$

$$\text{Output} = \frac{4}{\omega}\left[J_1\left(\frac{\omega b}{v}\right) \cos \frac{\omega a}{2v} \sin \omega\left(t_0 + \frac{a}{2v}\right) - \frac{1}{2} J_2\left(\frac{2\omega b}{v}\right) \cos \frac{2\omega a}{2v} \sin 2\omega\left(t_0 + \frac{a}{2v}\right) + \frac{1}{3} J_3\left(\frac{3\omega b}{v}\right) \cos \frac{3\omega a}{2v} \sin 3\omega\left(t_0 + \frac{a}{2v}\right) - \ldots\ldots + \ldots\ldots\ldots\right]. \quad (17)$$

CASE 3

Modulating edges of image are aligned as in Fig. 3c.

For this case the exposure in S_1 is identical to that for Case 1, Eq (*5*), but the exposure in S_2 becomes

$$*c_2 = t_2 - t_0 = (a/v) + (b/v) \sin \omega t_2. \quad (18)$$

This is so because in this case the exposures in each sound track begin at the same instant (t_0). Then, following the same development as in Case 1,

$$c_2 = t_2 - t_0 = \frac{a}{v} + \frac{2}{\omega} \sum_1^\infty \frac{1}{n} Jn\left(\frac{n\omega b}{v}\right) \sin n\omega\left(t_0 + \frac{a}{v}\right). \quad (19)$$

Push-pull output from the film is Eq (*19*) minus Eq (*5*).

$$\text{Output} = c_2 - c_1 = \frac{2}{\omega}\sum_1^\infty \frac{1}{n}\left[Jn\left(\frac{n\omega b}{v}\right) - Jn\left(\frac{-n\omega b}{v}\right)\right] \sin n\omega\left(t_0 + \frac{a}{v}\right) \tag{20}$$

$$\text{If } n \text{ is an odd number } Jn\left(\frac{n\omega b}{v}\right) - Jn\left(\frac{-n\omega b}{v}\right) = 2Jn\left(\frac{n\omega b}{v}\right). \tag{21}$$

$$\text{If } n \text{ is an even number } Jn\left(\frac{n\omega b}{v}\right) - Jn\left(\frac{-n\omega b}{v}\right) = 0. \tag{22}$$

Because of (*21*) and (*22*), the output in Eq (*20*) becomes

$$\text{Output} = \frac{4}{\omega}\left[J_1\left(\frac{\omega b}{v}\right)\sin\omega\left(t_0 + \frac{a}{v}\right) + \frac{1}{3}J_3\left(\frac{3\omega b}{v}\right)\sin 3\omega\left(t_0 + \frac{a}{v}\right) + \ldots\right]. \tag{23}$$

CASE 4

Four ribbon light valve operating in push-pull.

In this case in order to refer the exposures in the two sound tracks to the same instant of time (t_0), it is convenient to determine individually the following partial exposures:

$$^*c_1 = t_0 - t_1 = \frac{S_1}{v} = \frac{a}{2v} - \frac{b}{2v}\sin\omega t_1 = \frac{a}{2v} - \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{n\omega b}{2v}\right)\sin n\omega\left(t_0 - \frac{a}{2v}\right) \tag{24}$$

$$c_2 = t_2 - t_0 = \frac{S_2}{v} = \frac{a}{2v} - \frac{b}{2v}\sin\omega t_2 = \frac{a}{2v} + \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{2v}\right)\sin n\omega\left(t_0 + \frac{a}{2v}\right) \tag{25}$$

$$c_3 = t_0 - t_3 = \frac{S_3}{v} = \frac{a}{2v} + \frac{b}{2v}\sin\omega t_3 = \frac{a}{2v} - \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{-n\omega b}{2v}\right)\sin n\omega\left(t_0 - \frac{a}{2v}\right) \tag{26}$$

$$c_4 = t_4 - t_0 = \frac{S_4}{v} = \frac{a}{2v} + \frac{b}{2v}\sin\omega t_4 = \frac{a}{2v} + \frac{2}{\omega}\sum_1^\infty \frac{1}{n} Jn\left(\frac{n\omega b}{2v}\right)\sin n\omega\left(t_0 + \frac{a}{2v}\right) \tag{27}$$

The full exposure of sound track No. *1* will then be

$$E_1 = c_1 + c_2 = \frac{a}{v} + \frac{2}{\omega}\sum_1^\infty \frac{1}{n}\left[Jn\left(\frac{-n\omega b}{2v}\right)\sin n\omega\left(t_0 + \frac{a}{2v}\right) - Jn\left(\frac{n\omega b}{2v}\right)\sin n\omega\left(t_0 - \frac{a}{2v}\right)\right] \quad (28)$$

and similarly for sound track No. *2*

$$E_2 = c_3 + c_4 = \frac{a}{v} + \frac{2}{\omega}\sum_1^\infty \frac{1}{n}\left[Jn\left(\frac{n\omega b}{2v}\right)\sin n\omega\left(t_0 + \frac{a}{2v}\right) - Jn\left(\frac{-n\omega b}{2v}\right)\sin n\omega\left(t_0 - \frac{a}{2v}\right)\right]. \quad (29)$$

Push-pull output, Eq (*29*) minus Eq (*28*), is

$$\text{Output} = E_2 - E_1 = \frac{4}{\omega}\sum_1^\infty \frac{1}{n}\left[Jn\left(\frac{n\omega b}{2v}\right) - Jn\left(\frac{-n\omega b}{2v}\right)\right]\sin n\omega\left(t_0 + \frac{a}{2v}\right) - \left[Jn\left(\frac{-n\omega b}{2v}\right) - Jn\left(\frac{n\omega b}{2v}\right)\right]\sin n\omega\left(t_0 - \frac{a}{2v}\right) \quad (30)$$

$$\text{for } n \text{ odd} \left[Jn\left(\frac{n\omega b}{2v}\right) - Jn\left(\frac{-n\omega b}{2v}\right)\right] = 2Jn\left(\frac{n\omega b}{2v}\right)$$

$$\text{for } n \text{ even} \left[Jn\left(\frac{n\omega b}{2v}\right) - Jn\left(\frac{-n\omega b}{2v}\right)\right] = 0$$

$$\text{for } n \text{ odd} \left[Jn\left(\frac{-n\omega b}{2v}\right) - Jn\left(\frac{n\omega b}{2v}\right)\right] = -2Jn\left(\frac{n\omega b}{2v}\right)$$

$$\text{for } n \text{ even} \left[Jn\left(\frac{-n\omega b}{2v}\right) - Jn\left(\frac{n\omega b}{2v}\right)\right] = 0$$

so·that in Eq (*30*) the odd harmonics exist and the even harmonics vanish. Eq (*30*) can then be written

$$\text{Output} = E_2 - E_1 = \frac{8}{\omega}\left[\sum_1^\infty \frac{1}{n} Jn\left(\frac{n\omega b}{2v}\right)\left\{\sin n\omega\left(t_0 + \frac{a}{2v}\right) + \sin n\omega\left(t_0 - \frac{a}{2v}\right)\right\}\right] \quad (31)$$

$$= \frac{8}{\omega}\left[\sum_1^\infty \frac{1}{n} Jn\left(\frac{n\omega b}{2v}\right)\cos\frac{n\omega a}{2v}\sin n\omega t_0\right] \quad (32)$$

and since in (*32*) the (n) are all odd numbers, (*32*) expands into

$$\text{Output} = E_2 - E_1 = \frac{8}{\omega}\left[J_1\left(\frac{\omega b}{2v}\right) \cos\frac{\omega a}{2v} \sin\omega t_0 + \frac{1}{3} J_3\left(\frac{3\omega b}{2v}\right) \cos\frac{3\omega a}{2v} \sin 3\omega t_0 + \ldots \right]. \tag{33}$$

---

* In the above analysis, the following symbols were used:

Three Ribbon Push-Pull Light Valve

t_0 = instant when the exposure in S_1 begins.
t_1 = instant when the exposure in S_1 ends.
t_1 = instant when the exposure in S_2 begins.
t_2 = instant when the exposure in S_2 ends.

Four Ribbon Push-Pull Light Valve

t_0 = time of reference for S_1, S_2, S_3, S_4.
t_1 = instant when the exposure in S_1 begins.
t_2 = instant when the exposure in S_2 begins.
t_3 = instant when the exposure in S_3 begins.
t_4 = instant when the exposure in S_4 begins.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

27, 9 (Sept. 1946)

The Camera and Production Value (p. 312)	H. A. Lightman
Photographing the Underwater Atomic Bomb Test at Bikini (p. 315)	L. W. Knechtel
Carbon Arc Lighting for 16-Mm Color Production (p. 318)	A. Stensvold
High Fidelity Sound Printing for 16-Mm Films (p. 322)	L. N. Christiansen
duPont Perfects Film for Television (p. 325)	

27, 10 (Oct. 1946)

Greatest Photographic Organization in History Shot Bikini Blast (p. 352)	G. Warrenton
New Filter Technique for Color Cinematography (p. 356)	R. Rennahan
Mitchell's New 16-Mm Professional Camera (p. 376)	

Bell Laboratories Record

24, 10 (Oct. 1946)

Fastax at Bikini (p. 358)	J. H. Waddell

Electronic Engineering

18, 224 (Oct. 1946)

A Timer for Photo-Printing (p. 300)	N. Phelp and F. Tappenden
Line Scanning Systems for Television (p. 302)	A. M. Spooner
16-Mm Sound-on-Film Recorders (p. 309)	J. Neil

International Projectionist

21, 9 (Sept. 1946)

The Forest Electronic Arc Lamp (p. 5)	J. K. Elderkin
RCA's New Blue-Sensitive Phototube (p. 8)	J. D. Phyfe
The Laboratory Operator (p. 10)	R. L. McKnight

Better Sound-Reproducing Equipment (p. 12)	C. VERITAS
Telefilm Race Track Control (p. 23)	
21, 10 (Oct. 1946)	
The Forest Electronic Arc Lamp (p. 12)	J. K. ELDERKIN
Some Historic Firsts: The Orthophonic Phonograph (p. 16)	
The Technicolor Cameraman (p. 20)	W. HOCH

Acoustical Society of America, Journal

18, 2 (Oct. 1946)	
Measurement of Recording Characteristics by Means of Light Patterns (p. 387)	B. B. BAUER
The Effect of Non-Uniform Wall Distributions of Absorbing Material on the Acoustics of Rooms (p. 472)	H. FESHBACH AND C. M. HARRIS

Institution of Electrical Engineers, Journal

93, 69, Pt. 1 (Sept. 1946)	
A Method of Transmitting Sound on the Vision Carrier of a Television System (p. 415)	D. I. LAWSON, A. V. LORD, AND S. R. KHARBANDA
93, 25, Pt. 3 (Sept. 1946)	
Approximate Method of Calculating Reflections in Television Transmission (p. 352)	D. A. BELL

SOCIETY ANNOUNCEMENTS

JOURNAL AWARD

The SMPE Journal Award for 1946 was presented to Ralph H. Talbot for his paper "The Projection Life of Film," published in the JOURNAL of August 1945. The award, given annually for the most outstanding paper originally published in the JOURNAL during the preceding year, was announced by President D. E. Hyndman at the banquet held on October 23 during the 60th Semiannual Convention of the Society in Hollywood. A suitably inscribed certificate was presented to Mr. Talbot.

The paper was first presented before the Society at the May 1945 Technical Conference in Hollywood. A biographical sketch of the author, who is associated with the Eastman Kodak Company, Rochester, will be published in an early issue of the JOURNAL.

Honorable Mention was given to the paper by D. W. Epstein and I. G. Maloff, of Radio Corporation of America, entitled "Projection Television," published in June 1945; also to E. W. Kellogg, of the same organization, for his paper, "ABC of Photographic Sound Recording," published in March 1945; and to M. H. Sweet, of Ansco, for the paper entitled "The Densitometry of Modern Reversible Color Film," published in the June 1945 JOURNAL.

FELLOW AWARDS

In recognition of contributions made to the advancement of the motion picture industry and for services to the Society, seven Active members were elected to the grade of Fellow by action of the Board of Governors during 1946. At the banquet on October 23 in Hollywood, appropriate certificates were presented by President Hyndman to the following:

Ralph B. Austrian, RKO Television Corporation, New York.
Edmund A. Bertram, De Luxe Laboratories, New York.
John W. Boyle, Cinematographer, Hollywood.
Thomas T. Moulton, Twentieth Century-Fox Film Corporation, Beverly Hills, Calif.
William H. Offenhauser, Jr., Consultant to Columbia Broadcasting System, New York.
Lawrence T. Sachtleben, RCA Victor Division, Radio Corporation of America, Camden, N. J.
Abraham Shapiro, Ampro Corporation, Chicago.

HONOR ROLL

During the summer the Honorary Membership Committee submitted a recommendation to the Board of Governors proposing that the names of Theodore W. Case, Edward B. Craft, and Samuel L. Warner be added to the Honor Roll of the Society in view of their contributions to the technical progress of the motion picture industry. At a meeting on October 20, the Board approved the recommendation and voted to submit these names to the general membership for ratification.

The proposal was unanimously approved by qualified members present at a business session held on October 21 during the 60th Semiannual Convention. The names are listed in the Honor Roll on the back cover of the November JOURNAL, with other outstanding pioneers of the industry now deceased.

SCROLLS OF ACHIEVEMENT

As a highlight of the 60th Semiannual Convention in Hollywood, eight citations in recognition of outstanding achievement in the field of sound motion pictures were presented by the Society at the banquet on October 23. The awards were made in celebration of the Twentieth Anniversary of Talking Pictures, upon recommendation of the recently formed Committee on Citations. After unanimous approval by the Board of Governors, illuminated Scrolls of Achievement were prepared and awarded to the following:

Dr. Lee de Forest, in recognition of . . .

"His original researches which resulted in the invention of the Audion, a 3-electrode vacuum tube, destined to become a basic element in the development of telephonic communication, radio, and the sound motion picture;

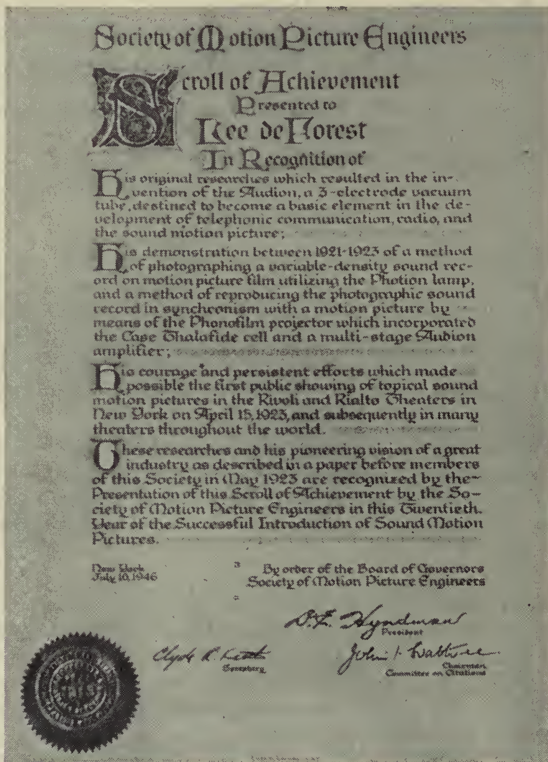
"His demonstration between 1921–1923 of a method of photographing a variable-density sound record on motion picture film utilizing the Photion lamp, and a method of reproducing the photographic sound record in synchronism with a motion picture by means of the Phonofilm projector which incorporated the Case Thalafide cell and a multistage Audion amplifier;

"His courage and persistent efforts which made possible the first public showing

of topical sound motion pictures in the Rivoli and Rialto Theaters in New York on April 15, 1923, and subsequently in many theaters throughout the world.

"These researches and his pioneering vision of a great industry as described in a paper before members of this Society in May 1923 are recognized by the Presentation of this Scroll of Achievement by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. Jack Gaines, of Hollywood, in the absence of Dr. de Forest.



Society of Motion Picture Engineers

Scroll of Achievement

Presented to

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New York
July 10, 1946

By order of the Board of Governors
Society of Motion Picture Engineers

President

Secretary

Chairman
Committee on Citations

FIG. 1. Scroll of Achievement presented to Dr. Lee de Forest.

Bell Telephone Laboratories, Inc., in recognition of . . .

"Their fundamental research in the art of communication from which came the development of sound recording and reproducing equipment;

"Their development of methods of high-quality recording on both disk and film;

"Their design of equipment that made possible the first commercially successful sound pictures.

"This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Dr. Harvey Fletcher, Director of Physical Research.

General Electric Company, in recognition of . . .

"Their development of the mirror oscillograph and its application to the practical recording of sound on film by the variable-area method;

"Their early recognition of the possibilities of sound reproduction and their technical developments in this art which resulted in greatly improved sound quality.

"This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. S. E. Gates, Resident Officer, Los Angeles.

Metro-Goldwyn-Mayer Studios, in recognition of . . .

"The impetus given by them to the design and development of theater speaker and reproducing systems which has greatly enhanced theater reproduction of sound;

"Their origination of wide push-pull recording which forms the basis for present practice and standards;

"Their initiation of many other methods and devices which have been made available to the industry and which, through improving the flexibility of production operations, have made possible a more complete expression of creative artistry.

"This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. Douglas Shearer.

RCA Victor Division, Radio Corporation of America, in recognition of . . .

"Their pioneering foresight and ingenuity and that of their predecessor, the Victor Talking Machine Co., in devising equipment and techniques for recording sound on disk for sound motion pictures;

"Their uninterrupted research and engineering developments in the field of motion picture sound which has been a source of continuous improvement in recordings and reproductions;

"Their development of manufacturing and distribution facilities which has played a vital role in translating the ideas of scientists and engineers into products and services for both producers and exhibitors of sound motion pictures.

"This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. Max C. Batsel.

Twentieth Century-Fox Film Corporation, in recognition of . . .

"The pioneering work of the Fox-Case Corporation in the development of motion pictures with sound on film having quality comparable with that of sound on disk;

"Their engineering developments which resulted in such innovations as the first studio wholly designed for commercial sound recording, and the perforated sound screen;

"Their continuing leadership as producers of sound motion pictures of high quality which included the first unified sound picture news service, 'Movietone News' (October 1927) and the first out-of-doors recorded feature picture, 'In Old Arizona' (December 1928).

"This Scroll of Achievement is presented by the Society of Motion Picture

Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. Earl I. Sponable, of Movietone News.

Western Electric Company, Inc., in recognition of . . .

"Their accomplishments in manufacturing sound recording and reproducing equipment speedily and in large quantities to meet the sudden and unprecedented demand from the motion picture industry to provide facilities to studios and theaters for the conversion from silent to sound pictures;

"Their introduction of improved equipment and methods of recording as the art developed.

"This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. T. K. Stevenson, Vice-President.

Westinghouse Electric and Manufacturing Company, in recognition of . . .

"Their pioneering efforts in the development of sound recording and sound reproduction for motion pictures; and

"The assistance they have given to engineers in standardization of methods and equipment in the motion picture art.

"This Scroll of Achievement is presented by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures."

The Scroll was received by Mr. Charles A. Dostal, Vice-President, San Francisco.

Other citations presented in 1946 by the Board of Governors, upon recommendation of the Committee on Citations, were to Thomas Armat on the occasion of the Fiftieth Anniversary of the first exhibition of motion pictures in a theater, and to Warner Brothers in recognition of their pioneering courage and efforts in the development of sound recording and sound reproduction for motion pictures, reported in the August 1946 JOURNAL.

ENGINEERING SOCIETIES COUNCIL

The Atlantic Coast Section of the Society is a charter member of the recently formed Engineering Societies Council of New York. As in numerous other cities, the Council is organized for the purpose of promoting the common interests of engineers and encouraging cooperation between the various engineering societies. Other charter members of the Council are:

American Institute of Chemical Engineers.
American Institute of Electrical Engineers.
American Institute of Mining and Metallurgical Engineers.
American Society of Heating and Ventilating Engineers.
American Society of Mechanical Engineers.
American Society for Metals.
American Society of Safety Engineers.
American Society for Testing Materials.
American Society of Tool Engineers.
American Chemical Society.
American Welding Society.
Illuminating Engineering Society.
Institute of Radio Engineers.

Two persons are selected by each member society as representatives to the Council. The present representatives of the Atlantic Coast Section are James Frank, Jr., and C. R. Keith. While the first meetings have been largely concerned with organization, it is anticipated that the Council will soon be taking an active part in engineering affairs in New York City.

SAMUEL L. WARNER MEMORIAL AWARD

President D. E. Hyndman announced at the 60th Semiannual Convention that the Board of Governors of the Society had unanimously and enthusiastically accepted the offer of Warner Bros. Pictures to establish an SMPE Samuel L. Warner Memorial Award. The award will be a suitably designed gold medal and appropriate certificate to be presented annually to any individual contributing an engineering or technical invention or improvement in the art of motion picture production, distribution, or exhibition which is considered a recent advance in the industry.

The first award will be made in 1947, and a committee to formulate rules and procedure for making the awards has been appointed.

ATLANTIC COAST SECTION MEETING

The problems of maintaining motion picture theater sound equipment were discussed at the November 13 meeting of the Atlantic Coast Section of the Society by E. S. Seeley, Chief Engineer of the Altec Service Corporation, New York. Choosing as his title, "The Contribution of Theater Service to 20 Years of Motion Picture Sound Progress," Mr. Seeley described a number of conditions which had to be met during war emergencies and scarce material and parts, and demonstrated the effect on sound quality resulting from the introduction of noiseless recording, the objections to 6-cycle and 96-cycle flutter, and the effect on sound quality owing to deterioration of equipment caused by lack of service.

Mr. Seeley said that national service organizations would play a large part in the successful introduction of new developments in the future. While these developments are not commercially available today, they might involve such items as automatic volume control, stereophonic sight and sound, television, panoramic or wide-angle sound origin, extended frequency and volume range, and new color film.

Throughout his presentation Mr. Seeley gave many interesting test film demonstrations of sound quality and methods of checking equipment.

The meeting, held in the Twentieth Century-Fox Little Theater, New York, was opened with an enjoyable motion picture short.

MIDWEST SECTION MEETING

A large audience of members and guests of the Midwest Section of the Society in Chicago heard John A. Maurer describe the Maurer film recording equipment and new Maurer camera at a meeting held November 14. Mr. Maurer reviewed the status of sound-on-film recording and related picture problems. Resolution in sound and picture, as theoretical and practical limits, was discussed and demonstrated by test films.

The Maurer equipment was analyzed and salient features elaborated. Of particular interest was the intermittent which utilizes a long intermittent rest period instead of registration pins to achieve steadiness. Recording optics are made of precision polished cylindrical surfaces solely, allowing resolution in excess of available films. The details of the sound drum stabilizer were analyzed and caused considerable interest.

The meeting was held in the quarters of the Western Society of Engineers, and was attended by many members of The Institute of Radio Engineers and The Acoustical Society of America.

PACIFIC COAST SECTION

A symposium on "Special Equipment" was held at the November 26 meeting of the Pacific Coast Section of the Society in the ERPD Review Room, Hollywood. The speakers were Kurt Singer, of Radio Corporation of America, Philip E. Brigandi, of RKO Radio Pictures, J. K. Hilliard, of Altec Lansing Corp., Carroll Dunning, of Dunning Color, R. Morgan, of Norman B. Neely Enterprises, and G. A. Mitchell, of Mitchell Camera Company.

In discussing the need and development of special equipment for the motion picture industry, Mr. Singer and Mr. Brigandi described a variable dip filter and its application to studio use. The need for the filter was called to RCA's attention when an arc whistle was inadvertently picked up on a Technicolor production. Commutator ripple modulation of the illuminating arcs had been recorded on scenes whose retaking would have involved a prohibitive cost. The arc whistle was satisfactorily eliminated by the dip filter and the costly scenes made usable. A demonstration of the variable dip filter was given.

Two new loudspeakers and a new amplifier were described and displayed by Mr. Hilliard. The smaller of the two loudspeakers is designed to give high-quality reproduction as applied to small portable cabinets such as used in the 16-mm field. The larger loudspeaker, intended for high-quality monitoring, is designed to give good high-frequency distribution and comparable high-quality reproduction of low frequencies. The amplifier was described as a 40-watt beam power unit designed primarily for use in disk recording.

Mr. Dunning demonstrated a new development known as the "Animatic Projector." The portable equipment synchronized a disk record containing voice and sound effects with a frame-by-frame projection of stills from 16-mm film. The disk turntable actuates the picture changes at regular intervals of several seconds. The equipment is used currently for sales instruction, visual education and television.

A Sorensen a-c line voltage regulator was discussed and shown by Mr. Morgan, who presented slides of the circuits employed. The characteristics of the d-c voltage regulator were also described.

Mr. Mitchell gave a short résumé of the features of the new Mitchell professional 16-mm camera, which was displayed with its accessories.

President-elect Loren L. Ryder and Section officers and managers for 1947 were introduced to the members and guests.

Lively discussion of the papers presented made the meeting one of the most interesting held recently in Hollywood.

AMENDMENT OF BY-LAWS

Proposed amendment of By-Law XIII of the Constitution and By-Laws of the Society, authorizing the establishment of Student Chapters, as published on page 268 of the September JOURNAL, was discussed and voted on by qualified members present at a general business session of the Society on October 21 during the recent Hollywood Convention. It was unanimously approved.

OFFICERS, GOVERNORS, AND SECTION MANAGERS FOR 1947–1948

As a result of the recent elections, the following is a list of the Officers and Governors of the Society for terms beginning January 1, 1947:

** *President:* LOREN L. RYDER
** *Past-President:* DONALD E. HYNDMAN
** *Executive Vice-President:* EARL I. SPONABLE
* *Engineering Vice-President:* JOHN A. MAURER
** *Editorial Vice-President:* CLYDE R. KEITH
* *Financial Vice-President:* M. RICHARD BOYER
** *Convention Vice-President:* WILLIAM C. KUNZMANN
** *Secretary:* G. T. LORANCE
* *Treasurer:* E. A. BERTRAM

Governors from the Eastern and Central Time Zones:
* FRANK E. CARLSON
* ALAN W. COOK
** ROBERT M. CORBIN
** DAVID B. JOY
* PAUL J. LARSEN

Governors from the Mountain and Pacific Time Zones:
** JOHN W. BOYLE
** CHARLES R. DAILY
* JOHN G. FRAYNE
* WESLEY C. MILLER
** HOLLIS W. MOYSE

Officers and Managers of the Atlantic Coast Section for terms beginning January 1, 1947, are:

* *Chairman:* JAMES FRANK, JR.
* *Past-Chairman:* FRANK E. CAHILL, JR.
* *Secretary-Treasurer:* H. EDWARD WHITE
Managers: * HERBERT BARNETT
* HOLLIS D. BRADBURY
** F. J. GRIGNON
** THEODORE LAWRENCE
* JACK A. NORLING
** WILLIAM H. RIVERS

Officers and Managers of the Midwest Section effective January 1, 1947, are:

* *Chairman:* A. SHAPIRO
* *Secretary-Treasurer:* ROBERT E. LEWIS
Managers: * OSCAR B. DEPUE
** WILLIAM C. DEVRY
* S. A. LUKES
** C. E. PHILLIMORE
* C. H. STONE
** R. T. VAN NIMAN

Officers and Managers of the Pacific Coast Section taking office as of January 1, 1947, are:

* *Chairman:* WALLACE V. WOLFE
* *Past-Chairman:* HOLLIS W. MOYSE
* *Secretary-Treasurer:* S. P. SOLOW
Managers: * GERALD M. BEST
** A. C. BLANEY
* P. E. BRIGANDI
** F. L. EICH
* GORDON E. SAWYER
** N. L. SIMMONS

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* Term expires December 31, 1947.
** Term expires December 31, 1948.

BACK ISSUES OF JOURNAL AVAILABLE

We are passing along to interested members information on the availability of sets of back issues of the JOURNAL. Many of the issues involved are now out of stock and cannot be obtained through the Society. Since we have received requests for such sets from time to time, we are glad to cooperate in offering these JOURNALS to the membership. Details of price, payment, and shipment must be arranged direct with the owners concerned.

E. W. Nelson, 4525 Altgeld St., Chicago 39, Ill., offers to sell the following:

> Issues July 1934 through December 1934 (one vol.), bound in standard library blue cloth binding, gold lettering, $4.00. Issues January 1935 through December 1942 (bound as above, one year per vol.), 1935 vol. includes 1930–35 cumulative index, $8.00 each. Unbound issues, January 1943 through December 1946, $6.00 per year. Entire lot $90.00, f.o.b. Chicago.

Mr. Nelson will arrange to have the single issues bound by the same book binder, should the purchaser desire. These JOURNALS are in excellent condition, Mr. Nelson states.

Another set of JOURNALS, beginning with the January 1930 issue through December 1946, is available from M. W. Palmer, 468 Riverside Drive, New York 27, N. Y. These are single copies and Mr. Palmer reports that they are in good condition. Details as to price, *etc.*, should be discussed with Mr. Palmer direct.

INCREASE IN MEMBERSHIP DUES

Personal letters were recently mailed to all Associate and Student members of the Society by M. R. Boyer, Financial Vice-President, announcing an increase in annual membership dues. At the meeting of the Board of Governors held during the 60th Semiannual Convention in Hollywood, it was brought to the attention of the Board that our present Associate and Student membership dues were insufficient to cover the increased cost of JOURNAL publication and administration.

The Board, therefore, took the only action possible and voted to raise the dues of Associate members from $7.50 to $10, and of Student members from $3 to $5, annually. Bills for 1947 dues for these two grades, therefore, will show this increase.

At this time, Mr. Boyer would like to urge the many Associate members who are eligible for Active membership to consider applying for this higher grade membership in the Society. Many members find that active participation in Society affairs materially increases the value of the Society to them and their companies. Since only members in the higher grades are eligible to vote and hold office, opportunities for participating in Society affairs are obviously better for members in the Active grade.

INCREASE IN JOURNAL SUBSCRIPTION RATE

Owing to increased costs of JOURNAL publication and administration, the Board of Governors of the Society has voted to raise the nonmember subscription rate to the JOURNAL from $8 to $10 annually, effective January 1, 1947. Single copies will be increased to $1.25 each. The Board also voted to discontinue discounts for subscriptions and single copies received through accredited agencies, effective January 1, 1947.

CORRECTION

In the paper "Factors Governing the Frequency Response of a Variable-Area Film Recording Channel," by M. Rettinger and K. Singer, published in the JOURNAL, **47**, 4 (Oct. 1946), the authors request that a change be made on p. 303. The sentence in the eighth line beginning "For this reason. . ." should read:

"For this reason, the reverberation time at the lower registers is usually longer than for the extreme high tones. This accentuation or loss may be expressed by. . ."

We are grieved to announce the death of Joseph E. Robin, Active member of the Society, on December 21, 1946, in Palisades, New Jersey.

Terry Ramsaye, Editor of the Motion Picture Herald, says...

¶"*The Technique of Motion Picture Production* is the first unified presentation of modern technical practices in motion picture production . . . Compact and complete . . . In plain terms that any interested layman can understand. . .

¶"This volume is indicated on the desk of anybody who wants to know about the motion picture and how it is made."

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Each section written by a specialist in the motion picture industry. . . Authentic information on various technical problems of motion picture production. . . . A useful and valuable reference for technicians, students, librarians, and others desiring technological data on the motion picture industry compiled in one volume.

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* 20% discount to members in good standing if ordered through SMPE. Orders must be accompanied by check or money order, and include 2% sales tax if delivered in New York City.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED
INDEXES

VOLUME 47
JULY–DECEMBER, 1946

AUTHOR INDEX, VOLUME 47

JULY–DECEMBER, 1946

CLASSIFIED INDEX, VOLUME 47

JULY–DECEMBER, 1946